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Marion T. Jackson

PROCEEDINGS

of the

Indiana Academy *of* Science

Founded December 29, 1885

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Volume 75
1965

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William R. Eberly, Editor
Manchester College
North Manchester, Indiana

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Spring Meeting
April 30-May 1
Culver Military Academy

Fall Meeting
October 7-9
University of Notre Dame

Published at Indianapolis, Indiana
1966

1. The permanent address of the Academy is the Indiana State Library, 140 N. Senate Ave., Indianapolis 4, Indiana.

2. **Instructions for Authors** appear at the end of this volume, P. 330.

3. **Exchanges.** Items sent in exchange for the Proceedings and correspondence concerning exchange arrangements should be addressed:
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5. **Reprints of technical papers** can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

6. The Constitution and By-Laws reprinted from v. 74 are available to members upon application to the Secretary. Necrologies reprinted from the various volumes can be supplied relatives and friends of deceased members by the Secretary.

7. Officers whose names and addresses are not known to correspondents may be addressed care of the State Library. Papers published in the Proceedings of the Academy of Science are abstracted or indexed in appropriate services listed here:

Annotated Bibliography of Economic Geology

Bibliography of Agriculture

Bibliography of North American Geology

Biological Abstracts

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Chemisches Zentralblatt

Current Geographical Publications

Geological Abstracts

Mathematics Reviews

Metallurgical Abstracts

Psychological Abstracts

Review of Applied Entomology

The Torrey Bulletin

Zoological Record

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Officers and Committees

OFFICERS FOR 1965

President	Frank J. Welcher, Indiana University (Indianapolis Center)
President Elect	Carrolle A. Markle, Earlham College
Secretary	Clarence F. Dineen, St. Mary's College
Treasurer	James C. List, Ball State University
Editor	Richard A. Laubengayer, Wabash College
Director of Public Relations	Frank N. Young, Indiana University

CHAIRMEN ELECTED BY THE DIVISIONS

Anthropology	King B. Hunter, Indiana University
Bacteriology	Morris Wagner, University of Notre Dame
Botany	John F. Schafer, Purdue University
Chemistry	Kenneth Cook, Anderson College
Entomology	Mrs. Gertrude L. Ward, Earlham College
Geology and Geography	John B. Patton, Indiana University
History of Science	Nellie Coats, State Library
Mathematics (Acting)	Arnold Johnson, University of Notre Dame
Physics	H. K. Hughes, Indiana State College
Plant Taxonomy	Gayton C. Marks, Valparaiso University
Psychology (Acting)	John F. Santos, University of Notre Dame
Soil Science	Helmut Kohnke, Purdue University
Zoology	William Eberly, Manchester College

EXECUTIVE COMMITTEE

(Past Presidents,* Current Officers, Divisional Chairmen, Committee Chairmen)

*Baldinger, L. H.
Carlson, K. H.
*Christy, O. B.
*Cleland, R. F.
Coats, Nellie
Cook, Kenneth
Daily, Mrs. W. A.
*Daily, W. A.
*Davis, J. J.
*Day, H. G.
*Degering, E. F.
Dineen, C. F.
Eberly, W. R.
*Edington, W. E.
*Edwards, P. D.
*Girton, R. E.
*Guard, A. T.
*Haenisch, E. L.
Hughes, H. K.
Heniser, V. H.
Hunter, K. B.
*Johnson, W. H.
Kaufman, Karl
Kessel, W. G.
Kohnke, Helmut
Laubengayer, R. A.
*Lilly, Eli
List, J. C.
Markle, C. A.
*Markle, M. S.
Marks, G. C.
*Mellon, M. G.
*Meyer, A. H.
*Michaud, H. H.
Miller, G. R.
*Morgan, W. P.
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*Porter, C. L.
*Powell, H. M.
Schafer, J. F.
Seymour, K.
Stockton, Sister M. Rose
*Visher, S. S.
Wagner, Morris
*Wallace, F. N.
Ward, Mrs. G. L.
*Weatherwax, P.
Webster, J. D.
*Welch, W. M.
Welcher, F. J.
Winslow, D. R.
Young, F. N.
Youse, H.

BUDGET COMMITTEE

Consisting of: President (Welcher), President Elect (Markle), Secretary (Dineen), Treasurer (List), Editor (Laubengayer), Director of Public Relations (Young), Retiring President (Haenisch), Director of Junior Academy (Winslow), Library Committee (Coats), Program Committee (Baldinger), Youth Activities Committee (Heniser), Relation of Academy to State (Daily). Invited participant: Former Program Chairman (Brooker).

COMMITTEES ELECTED BY THE ACADEMY

Trustees of the Academy Foundation: Chairman, W. P. Morgan, Indiana Central College (1966); William A. Daily, Lilly Company (1965).

Bonding Trustees: Chairman, Scott McCoy, Technical High School, Indianapolis; D. J. Cook, DePauw University.

Research Grants: Chairman, P. Weatherwax, Indiana University (1966); K. M. Seymour, Butler University (1965); A. A. Lindsey, Purdue University (1968); J. F. Hart, Indiana University (1967); O. K. Behrens, Indianapolis (1969).

COMMITTEES APPOINTED BY THE PRESIDENT

(President an ex officio member of all committees)

Academy Representative on the Council of the A.A.A.S.: W. H. Johnson, Wabash College.

Auditing Committee: Chairman, K. H. Carlson, Valparaiso University; W. W. Bloom, Valparaiso University.

Youth Activities Committee: Chairman, Virgil Heniser, Indiana University; James Ashley, South Bend Schools; Mrs. Eliz. Crider, Washington School, Indianapolis; Karl Kaufman, Butler University; Wm. Kessel, Indiana State University; Paul Klinge, Indiana University; Ralph Lefler, Purdue University; Howard Michaud, Purdue University; Woodrow Pemberton, Bosse School, Evansville; Wm. Smith, Howe School, Indianapolis; Erwin Steinkamp, New Albany School; Don Winslow, University School, Bloomington; ex officio: Robert Kent, State Dept. of Public Instruction; Mrs. Marian Rector, Muncie.

Indiana Science Talent Search: Director, Virgil Heniser, Indiana University; L. H. Baldinger, University of Notre Dame; Clinton Gass, DePauw University; Robert Henry, Wabash College; S. N. Postlethwait, Purdue University; Harry Zimmack, Ball State University.

Indiana Science Fairs: State Coordinator, Karl Kaufman, Butler University; Regional Directors: Robert Brooker, Indiana Central College (Central Indiana Regional); Gerald Doeden, Ball State University (East Central Indiana Regional); P. V. Flannery, Purdue Calumet Center (Calumet Regional); Ronald Gibbs, Indiana University (South Central Indiana Regional); Ralph Green, Purdue University (Lafayette Regional); Roger Harned, Commercial Solvents Co.

(West Central Indiana Regional); Paul Hartman, Evansville College (Tri-State Regional); Brian Hill, Indiana University, Jeffersonville (Southeastern Indiana Regional); Emil Hoffman, University of Notre Dame (Northern Indiana Regional); A. C. Koester, Valparaiso University (Northwestern Indiana Regional); Leo Kuhn, Tri-State College (Northeastern Tri-State Regional); Robert E. Wise, Purdue University, Fort Wayne (Northeastern Indiana Regional).

Indiana Junior Academy of Science: Director, Don R. Winslow, University High School, Bloomington; Howard Michaud, Purdue University; Sister Marian Francis, Reitz Memorial High School, Evansville; Keith Hunning, New Haven High School; Miss Helen Reed, Manual High School, Indianapolis; Erwin Steinkamp, New Albany High School.

Visiting Scientists: Director, W. G. Kessel, Indiana State University; K. H. Carlson, Valparaiso University; Robert H. Cooper, Ball State University; Mrs. Eliz. Crider, Washington High School, Indianapolis; Ernest Litweiler, John Adams High School, South Bend.

Library: Chairman, Nellie Coats, Indiana State Library; Mrs. Lois Burton, Indiana State Library; Eli Lilly, Eli Lilly and Company; Bernard Malin, Eli Lilly and Company.

Program: Chairman, L. H. Baldinger, University of Notre Dame; Robert Anthony, University of Notre Dame; George Craig, University of Notre Dame; James Danehy, University of Notre Dame; P. L. Knight, St. Mary's College.

Publication: Chairman, R. A. Laubengayer, Wabash College; J. A. Clark, Department of Conservation; A. A. Lindsey, Purdue University.

Relation of Academy to State: Chairman, W. A. Daily, Eli Lilly and Company; J. A. Clark, Department of Conservation; C. F. Dineen (ex officio), St. Mary's College; R. A. Laubengayer, Wabash College.

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Robinson, Oakland City College; J. D. Webster, Hanover College; F. J. Zeller, Indiana University.

Fellows: Chairman, Chemistry: K. M. Seymour, Butler University (1967); Psychology: E. J. Asher, Purdue University (1966); Soil Science: S. Barber, Purdue University (1967); Zoology: W. R. Breneman, Indiana University (1967); Entomology: L. Chandler, Purdue University (1966); Anthropology: H. E. Driver, Indiana University (1966); Bacteriology: Dean Fraser, Indiana University (1967); Plant Taxonomy: A. T. Guard, Purdue University (1965); History of Science: G. F. Hennion, Notre Dame (1965); Physics: R. W. Lefler, Purdue University (1965); Geology and Geography: Benjamin Moulton, Indiana State University (1967); Mathematics: J. C. Polley, Wabash College (1965); Botany: W. H. Welch, DePauw University (1966).

Resolutions: Chairman, Howard Youse, DePauw University; Lawrence Baldinger, University of Notre Dame; Shelby Gerking, Indiana University.

Invitations: Chairman, Glen R. Miller, Goshen College; G. D. Lovell, Wabash College; W. P. Morgan, Indiana Central College; F. D. Rossini, University of Notre Dame.

Necrologist: Mrs. William A. Daily, Butler University.

Parliamentarian: Paul Weatherwax, Indiana University.

SPECIAL COMMITTEES APPOINTED BY THE PRESIDENT

Biological Survey: Chairman, J. D. Webster, Hanover College; Leland Chandler, Purdue University; Mrs. William A. Daily, Butler University; James R. Gammon, Earlham College; Charles Heiser, Indiana University; Grady L. Webster, Purdue University; Winona Welch, DePauw University; Frank Young, Indiana University.

Special Constitution Revision Committee: Chairman, Paul Weatherwax, Indiana University; R. H. Cooper, Ball State University; Wm. A. Daily, Eli Lilly and Company; Harry G. Day, Indiana University; Ray T. Everly, Purdue University; Edward L. Haenisch, Wabash College; Howard H. Michaud, Purdue University; Frank J. Welcher (ex officio), Indiana University.

Committee to Consider Change of Day of Fall Meeting: Chairman, Harry G. Day, Indiana University; Lawrence Baldinger, University of Notre Dame; Otto K. Behrens, Eli Lilly and Company; Robert Brooker, Indiana Central College; James C. List, Ball State University; Howard Michaud, Purdue University.

SPRING MEETING

CULVER MILITARY ACADEMY, Culver, Indiana

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

April 30, 1965

The meeting was called to order by the president, Dr. Frank J. Welcher, at 4:30 p.m. in the Little Theatre, Culver Military Academy.

The treasurer, Dr. James C. List, submitted the financial report for the period January 1, 1965, through April 15, 1965. A summary is as follows:

State Academy Accounts

Balance as of January 1, 1965	$ 7,238.83
Receipts through April 15, 1965	7,024.40
Disbursements through April 15, 1965	2,956.00
Balance as of April 15, 1965	11,307.23

National Science Foundation Accounts (GE 4306)

Balance as of January 1, 1965	$ 4,493.94
Receipts through April 15, 1965	5,000.00
Disbursements through April 15, 1965	6,471.95
Balance as of April 15, 1965	3,021.99

Special Constitution Revision Committee: Dr. Paul Weatherwax, chairman, discussed proposed amendments. In accordance with Art. VIII. AMENDMENTS; Sec. 1. The following amendments were proposed:

In Art. III, Sec. 1, of the Constitution, the list of officers shall be amended to read as follows: President, President-Elect, Secretary, Treasurer, Editor, and Director of Public Relations, and Sections numbered 7, 8, and 9 shall be rearranged and renumbered to conform with this change.

To Art. V, Sec. 1 (7) **Publication**, the following shall be added: The Editor shall serve as Chairman of this Committee.

The following articles shall be added to the By-Laws:

Art. X. GENERAL PROVISIONS

Notwithstanding any provision of this Constitution or these By-Laws which might be susceptible to a contrary construction:

(1) The Academy shall be organized and operated exclusively on a non-profit basis for scientific and educational purposes;

(2) No part of the net earnings or other resources of The Academy shall or may under any circumstances inure to the benefit of any private shareholder or individual;

(3) No substantial part of the activities of The Academy shall consist of carrying on propaganda or otherwise attempting to influence legislation;

(4) The Academy shall not participate, by publication or circulation of statements or other intervention, in any political campaign on behalf of any candidate for public office; and

(5) The Academy shall not:
  (a) lend any part of its income or corpus without the receipt of adequate security and a reasonable rate of interest to:
  (b) pay any compensation, in excess of a reasonable allowance for salaries or other compensation for personal services actually rendered to:
  (c) make any part of its services available on a preferential basis to:
  (d) make any substantial purchase of securities or other property, for more than adequate consideration in money or money's worth to:
  (e) sell any substantial part of its securities or other property, for less than an adequate consideration in money or money's worth to: or
  (f) engage in any other transaction which results in a substantial diversion of its income or corpus to:

a person who has made a substantial contribution to The Academy.

Art. XI. DISTRIBUTION ON DISSOLUTION

Upon dissolution of The Academy, its assets shall be distributed by the Executive Committee to one or more organizations qualifying under Section 501 (c) (3) or Section 501 (c) (6) of the Internal Revenue Code of 1954.

These proposed amendments to the constitution were approved by the Executive Committee and recommended that the amendments be submitted to the membership at the General Meeting.

Academy Foundation: The trustees of the Academy Foundation, Dr. William P. Morgan and William A. Daily, asked Mr. Richard C. Solaro, Assistant Trust Officer of the Indiana National Bank of Indianapolis, to explain legal aspects pertaining to the transfer of securities of The Indiana Academy of Science. After a discussion the following resolution was presented and approved:

"BE IT RESOLVED THAT, Dr. William P. Morgan and William A. Daily, the duly elected Chairman of the Trustees and Trustee, respectively, of the Indiana Academy of Science, Academy Foundation, are hereby jointly or individually authorized to sell, assign and endorse for transfer, including transfer to NOVUS & CO. as fiduciary nominee of The Indiana National Bank of Indianapolis, Indiana, certificates representing stocks, bonds, or other securities now registered or hereafter registered in the name of the Indiana Academy of Science, or in its name showing any special fund in addition to its name in the registration on the certificate."

Research Grants: Paul Weatherwax. Four grants totaling $900.00 were approved by the committee during the Fall Meeting, 1964. A statement of policy and of directions for making applications has been drawn up and is being revised. The revision will be presented to the Executive Committtee during the fall meeting (1965). A motion was approved to allocate research funds for grant-in-aid and for publication annually by the Budget Committee of The Academy.

Editor: Richard A. Laubengayer reported that the galley proofs for Volume 74 (1964) should be in the hands of the authors by the end of May. The Editor plans to issue a sheet of directions for the sectional chairmen.

Library: Miss Nellie Coats reported that upon presentation of the need for further support, Lilly Endowment Inc. made in March a second grant to the John Shepard Wright Memorial Library of $5,300.00.

Director of Public Relations: Frank N. Young requested news items from members of The Academy. A desire was expressed to have publicity throughout the year with emphasis prior to the Fall Meeting.

Special Committee to Consider Change of Day of the Fall Meeting: Harry G. Day. The committee reported that it would be advantageous to have a joint Saturday Meeting of the Senior and the Junior Academy. A motion was approved to have the Fall Meeting day of The Academy changed from Friday to Saturday on a three-year trial basis effective during the period 1966-68.

The interest in forming a Section in Ecology was discussed. A motion was approved to form a section on a three-year trial basis effective during the period 1966-68. It was suggested that an organizational meeting be held during the Fall Meeting (1965) at the University of Notre Dame with Dr. Donald Miller as Chairman.

A motion was approved to make Art. II, Sec. 4 (Emeritus Members) of the new Constitution retroactive to include those members with Emeritus status prior to the adoption of the new constitution. Emeritus membership was approved for Dr. Paul S. Rickett and Mr. Stephen S. Visher.

Approved October 8, 1965 CLARENCE F. DINEEN, Secretary

MINUTES OF THE GENERAL SESSION

May 1, 1965

Following the dinner meeting in the Culver Inn Dining Room, the formal business session was called to order by the President, Frank J. Welcher, at 8:00 p.m. President Welcher introduced Major General Delmar T. Spivey, USAF (Ret), Superintendent, Culver Military Academy. General Spivey welcomed The Academy and invited the members to tour and to enjoy the Culver Military Academy facilities.

The amendments to the Constitution which were approved by the Executive committee as printed in the minutes of that committee (April 30, 1965) were presented and approved by the membership of The Academy. These amendments will be presented to The Academy at the Fall Meeting, 1965, for final action.

The secretary presented the applications of twenty-three new members and six new clubs to the membership of The Academy. The applications were approved.

An illustrated lecture on "Wildflowers of Indiana" by Mr. and Mrs. Lloyd Beesley, Cedar Grove, Indiana, was the highlight of the evening. The lecture proved interesting and educational.

The Saturday Field Trips were announced: (1) Zoology—Visit to the Bass Lake Fish Hatchery, Gary Schnicke, Fish Management Biologist. (2) Botany—Ronn N. Minne and James V. Miracle, Culver Military Academy. (3) Geology and Soils—Gerald Johnson and Allan Schneider of the Geological Survey, State of Indiana, and H. P. Ulrich, Purdue University, Department of Agronomy. (4) Ornithology—Staff, Culver Military Academy.

Howard R. Youse, Chairman of the Resolutions Committee presented the following resolutions which were approved:

"WHEREAS: The Indiana Academy of Science is deeply grateful to the Culver Military Academy for placing their facilities at our disposal during our spring meeting, be it

RESOLVED: That the Indiana Academy members here assembled express their sincere thanks to the Culver Military Academy through Major General Delmar T. Spivey, USAF (Ret), Superintendent, for all the courtesies which have been shown the Indiana Academy during this meeting.

Special appreciation and thanks are due Mr. James Kurz, Manager of the Culver Inn, for the efficient handling of our housing and meals.

We also thank Dr. Lawrence H. Baldinger, Program Chairman, and all members and leaders of the field trips for their services."

Approved, October 8, 1965 Clarence F. Dineen, Secretary

FALL MEETING

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

University of Notre Dame, Notre Dame, Indiana

October 7, 1965

The Executive Committee meeting of the Indiana Academy of Science was held on October 7, 1965, in the Nieuwland Science Hall at the University of Notre Dame. The meeting was called to order at 7:00 p.m. by Frank J. Welcher, president of The Academy.

The minutes of the Executive Committee and the General Session of the Spring Meeting of The Academy (April 30, May 1) at Culver Military Academy were approved.

Treasurer—Dr. James C. List: Dr. List presented the treasurer's report: January 1 balance plus receipts in State Accounts as of September 30, 1965—$18,945.07; disbursements—$6,094.74; present balance—$12,850.33.

January 1 balance plus receipts in NSF funds as of September 30, 1965—$29,407.16; disbursements—$15,662.33; balance as of September 30, 1965—$13,744.83.

The Trustees of the Academy Research Endowment Fund: William A. Daily, chairman, reported as of October 7, 1965: in the Academy Research Fund, beginning balance—$812.04; receipts—$814.62; disbursements—$839.48; balance as of October 1—$787.18. In the John S. Wright Fund of the Academy Research Fund, a beginning balance—$2,149.67; receipts—$7,601.99; disbursements—$9,460.32; balance as of October 1, 1965—$291.34.

Youth Activities Committee: Virgil Heniser, chairman, reported that the major programs, namely, The Indiana Science Talent Search, The Indiana Science Fairs and the Indiana Junior Academy of Science, have been very successful and are developing. The number of high school science clubs increased recently from thirteen to 41.

Visiting Scientist Program: Dr. William G. Kessel, director, reported that the sixth consecutive year of The Visiting Scientist Program for Indiana High Schools was conducted during the 1964-65 academic year with a grant of $14,780 from The Special Projects in Science Education of The National Science Foundation. Reception by administration, teachers and students was excellent as has been the situation every year.

Library Committee: As reported at the Spring Meeting of The Academy in March, 1965, in response to an application, the Lilly Endowment Inc. made a second grant, this of $5,300, to The Academy's John Shepard Wright Memorial Library to employ personnel. A trained and experienced librarian has been employed and the work is progressing rapidly.

Committee on Research Grants: Dr. Paul Weatherwax, chairman, stated that one grant for $150 has been awarded since the Spring Meeting. Thus, a total of $1,050 has been granted during the entire year. A statement of policy and a set of instructions for making application have been prepared for prospective applicants. A motion was approved to have the secretary of The Academy distribute this information to all the institutions of higher learning in Indiana and to membership high school clubs.

Invitation Committee: In the best interest of all institutions concerned, the chairman (Glen R. Miller) proposed an alteration in the previously adopted three-year schedule of Fall Meetings. A motion was approved to revise the schedule to read: Fall Meeting, 1966—Indiana Institute of Technology, 1967—Wabash College, 1968—Ball State University.

Biological Survey Committee: The chairman, J. D. Webster, reported a decrease in the number of publications dealing with the flora and fauna of Indiana as compared to previous years. The full report follows.

The chairman of the Bacteriology Division, Morris Wagner, explained the difficulties involved in electing at this meeting a chairman for the Bacteriology division for 1966. A motion was passed to have Mr. Wagner remain as chairman until another chairman could be elected.

In accordance with Art. II (Membership), Sec. 4 (Emeritus Members) of the Constitution, Mr. Frank D. Kern and Mr. Grant T. Wickmire petitioned the Executive Committee for emeritus status. The petitions were approved.

A motion was approved to have The Academy go on record as supporting a prospectus for a Regional Educational Research Laboratory.

The Amendments to the Constitution which were approved at the Spring Meeting (April 30, 1965) were passed by the Executive Committee and will be presented at the General Session for final approval.

Approved October 8, 1965 CLARENCE F. DINEEN, Secretary

Biological Survey Committee, J. Dan Webster, Chairman

Publications of 1964-1965

Dealing with the Flora and Fauna of Indiana

Fungi, Uredinales:	Hennen, J. F., 1965. The species of *Uromyces* parasitic on the grass tribe Andropogonede. Mycologia (Includes Indiana records), **57**: 104-113. Cummins, B. G., 1966. The Uredinales that parasitize the Three-Awn Grasses. Proc. Ind. Acad. Sci. for 1965. In press. Cummins, G. B. and P. Ramachar, 1965. The species of *Puccinia* on the Paniceae. Mycopat. Mycol. Appl. (Includes Indiana records), **25**: 7-60.
Vascular Plants:	Bliss, L. C. and G. W. Cox, 1964. Plant community and soil variation within a Northern Indiana Prairie. Amer. Midl. Naturalist, **72**: 115-128. Glassman, S. F., 1964. Grass flora of the Chicago Region. Amer. Midl. Naturalist (Includes northwestern Indiana), **72**: 1-49. Jackson, M. T. Microclimatic Differences and their Effects on Spring Flowering Phenology. (Study done at Allee Memorial Woods, Parke County, Indiana.) Ecology, in press. Marks, G., 1966. An introduced *Polygonum* in Porter County. Proc. Ind. Acad. Sci. for 1965. In press. Mertens, T. R., 1965. Preliminary studies on the genus *Polygonum*, sect. *Polygonum* (Avicularia) in North America. Proc. Ind. Acad. Sci. for 1964. **74**: 307.
Crustacea:	Eberly, W. R., 1966. A new troglobitic Isopod (Asellidae) from Southern Indiana. Proc. Ind. Acad. Sci. for 1965. In press.
Insecta:	Chandler, L., 1966. Wasps of the tribes Stizini and Bembicini in Indiana. Proc. Ind. Acad. Sci. for 1965. In press. Siverly, R. E., 1965. Notes on the biology of *Psorophora ciliata* (Fabricius) in Indiana. Proc. Ind. Acad. Sci. for 1964. **74**: 194-195. Siverly, R. E., 1966. Occurrence of *Culiseta minnesotae* Barr in Indiana. Proc. Ind. Acad. Sci. for 1965. In press.
Pisces:	Erman, D. C. and R. E. Mumford, 1966. A preliminary list of the fishes of Tippecanoe County, Indiana. Proc. Ind. Acad. Sci. for 1965. In press.
Amphibia:	Rubin, D., 1965. Occurrence of the spadefoot toad, *Scaphiopus holbrooki* (Harlan), in Vigo County, Indiana. Herpetologica. **21**: 153-154.
Aves:	Baker, Mrs. H. A., 1964. Breeding census #46. Grazed, brushy fields and tree-bordered creek. Aud. Field Notes, **18**: 573-574. Kirkpatrick, R. D., 1966. The introduction of the Japanese Quail (*Coturnix c. japonica*) in Indiana. Proc. Ind. Acad. Sci. for 1965. In press. Indiana Audubon Society Members, 1965. Many titles in Indiana Audubon Quarterly, Vol. **43**.

Webster, J. D., 1964. Breeding bird census #7. Tornado-disturbed Beech-Maple forest. Aud. Field Notes, **18:** 548-549.

Webster, J. D., 1965. Winter bird population study #11. Tornado-disturbed Beech-Maple forest. Aud. Field Notes, **19**: 423-424.

Mammalia:

Humphrey, S. R. and J. B. Cope, 1966. A population dynamics study of a *Myotis lucifugus* colony in Boone County, Indiana. Proc. Ind. Acad. Sci. for 1965. In press.

Mumford, R. E., 1964. A melanistic prairie vole. Journal of Mammalogy, **45**: 150.

Whitaker, J. O., Jr. and Zimmer, G., 1965. Additional *Mustela nivalis* records for Indiana. J. Mamm., **46(3)**: 516.

Theses Completed and Placed on File, Dealing with the Flora and Fauna of Indiana

Fungi:

Mislivec, P. B., 1965. The importance of soil type and of soil pH as factors in the occurrence of the aspergilli in Vermillion County, Indiana. M.Sc. Indiana State.

Protozoa:

MacLean, Bonnie K. Internal parasitism of *Bombus* Spp. in Indiana. M.Sc. Purdue.

Insecta:

Eldridge, B. F., 1965. The influence of environmental factors on blood-feeding and hibernation in mosquitos of the *Culex pipiens* complex. Ph.D. Purdue.

Hendricks, D. E., 1964. The ectoparasites and other arthropod associates of *Citellus tridecemlineatus tridecemlineatus* (Mitchill). M.Sc. Purdue.

McWilliams, J. G., 1965. Seasonal distribution bionomics of mosquitoes in a woodlot, Tippecanoe County, Indiana. M.Sc. Purdue.

Wood, G. R., 1965. The insect pollinators of species and cultivars of *Cucurbita*. M.Sc. Purdue.

Amphibia, Reptilia:

Rubin, D., 1965. Amphibians and reptiles of Vigo County, Indiana. M.Sc. Indiana State.

Aves and Mammalis:

Gough (Meadows), Betty Jane, 1964. Seasonal use by birds and mammals of a wildlife food and cover planting. M.Sc. Purdue.

Shoesmith M. W., 1965. An evaluation of established multiflora rose hedges as wildlife habitat. M.Sc. Purdue.

General Ecology:

Erman, D. C., 1965. A preliminary aquatic study of impoundments at Jasper-Pulaski State Game Preserve in northwestern Indiana. M.Sc. Purdue.

Work in Progress, but not yet Published, Dealing with the Flora and Fauna of Indiana

Fungi:

Cummins, G. B. and A. C. Green. Purdue and Univ. Wisconsin. Rust fungi on Aveneae.

Cummins, G. B. Purdue. Manual of the grass rust fungi of the world.

Parmalee, J. A. Purdue. Revision of N. Amer. *Puccinia* on Compositae: Helianthae.

Vascular Plants:	Eilers, L. J. Purdue. A biosystematic study of the genus *Sullivantis*.
	Allen, P. Purdue. Detailed mapping of an undisturbed hardwood forest in Owen County, Indiana.
	Jackson, M. Purdue. Evaluation of two taxa of Indiana hard maples.
	Humbles, J. Indiana University. Indiana plant distribution records (A continuing study).
	Gordon, D. Indiana University. Monograph of *Gleditsia* (Leguminosae).
Insecta:	Munsee, J. R. Purdue. The ecology of ants in the spoil banks of a strip-mine.
	Hamon, J. H. and J. S. Hasiman. Indiana State. The succession of saprophagous arthropods on carasses of animals.
Pisces:	Whitaker, J. O., Jr., and D. C. Wallace. Indiana State. The fishes of Vigo County, Indiana.
Aves:	Williams, E. C., Jr. Wabash. Population studies on the box turtle, *Terrapene carolina*.
	Mumford, R. E. Purdue. Taxonomy and Distribution of the birds of Indiana.
	Hoekstra, T. W. Purdue. Ecology and population dynamics of gallinaceous birds on Crane Naval Ammunition Depot.
	Thurman, J. R. Purdue. Ruffed grouse ecology in southern Indiana woodlands.
	Hamon, J. H. Indiana State. The systematic position of the Chat, *Icteria virens*.
	Wright. V. L. Purdue. Ecology of the Hungarian Partridge in Indiana.
Aves and Mammalia:	Burton, J. P. Purdue. Wildlife management of strip-mined land in southwestern Indiana. First study.
	Jones, G. S. Purdue. Wildlife management of strip-mined land in southwestern Indiana. Second study.
	Martinka, R. R. Purdue. Wildlife population changes following multiflora rose hedge eradication.
Mammalia:	Mumford, R. E. A statewide survey of the present status of Indiana mammals.
	Whitaker, J. C., Jr. Indiana State. Mammals of Vigo County, Indiana.
	White, C. Purdue. The dynamics and ecology of the white-tailed deer (*Odocoileus virginianus*) in southern Indiana.
General Ecology:	Hamon, J. H. Indiana State. A survey of parasites of some Indiana birds.
	Troyer, Barbara. Indiana State. Some preliminary studies on the succession of bacteria responsible for maceration of birds.

MINUTES OF THE GENERAL SESSION

University of Notre Dame, October 8, 1965

The annual meeting of the Indiana Academy of Science was held in the auditorium of the Memorial Library at the University of Notre Dame, Notre Dame, Indiana, on October 8, 1965. Dr. Frank J. Welcher, President of The Academy, called the meeting to order at 9:30 a.m.

Rev. Joseph S. McGrath, University of Notre Dame, welcomed The Academy to the Campus. Dr. Frederick D. Rossini, Dean of the College of Science, University of Notre Dame, spoke on the "Centennial of Science."

The minutes of the Executive Committee Meeting on October 7, 1965, were read and approved as read.

Mrs. William A. Daily, The Academy Necrologist, read a biographical sketch of members who had died since the 1964 Annual Meeting. These sketches are printed under Necrology in the Proceedings of the Indiana Academy of Science.

Dr. Paul Weatherwax, chairman of the Special Constitution Revision Committee, reviewed the actions of the committee. In accordance with the recommendations of the Executive Committee, Dr. Weatherwax moved that the amendments to the Constitution, as printed in the minutes of the Executive Committee, April 30, 1965, be adopted by The Academy. The motion was carried. Thus, the amendments are an official part of the Constitution (Article VIII. Amendments, Sec. 1).

President Welcher introduced Dr. Milton Burton, Professor of Chemistry, Director of the Radiation Laboratory, University of Notre Dame. Dr. Burton delivered a stimulating lecture on "The Nature of Science and Research."

The meeting was adjourned at 11:25 a.m.

The annual dinner meeting of The Academy was held in the North Dining Hall of the University of Notre Dame at 6:30 p.m. Dr. Carrolle A. Markle, President-Elect of The Academy, presided. Dr. Markle introduced the guests and officers at the speaker's table and gave special recognition to out-of-state guests.

Dr. James C. List presented the applications for new membership to The Academy. The applications were approved.

Dr. Howard Youse presented the following resolutions to The Academy which were approved:

1. That the Academy members here assembled express their sincere thanks to the University of Notre Dame through Rev. Theodore M. Hesburgh, President of the University for all the courtesies which have been extended to the Academy during this meeting.

2. Special appreciation and thanks are due Dr. Lawrence H. Baldinger and his committee for the planning of the general session and the efficient manner in which all other arrangements for the conduction of the Academy business were made.

3. Indiana Dunes National Lakeshore

WHEREAS: Many scientists and educators have expressed their personal support for the Indiana Dunes National Lakeshore, including the scientifically valuable non-contiguous area, as planned by the National Park Service, and

WHEREAS: The important role of this unique area in the development of biology and geology is universally appreciated, be it therefore

RESOLVED: That the Indiana Academy of Science favors the Indiana Dunes National Lakeshore proposal, and be it further

RESOLVED: That the Secretary of the Academy be instructed to convey this resolution to appropriate officials, and that our Director of Public Relations be empowered to release it to the public media.

Dr. Harry G. Day, chairman of the nominating committee, read the names of the divisional chairmen for 1966 which had been elected in the divisional meetings. They are as follows: Anthropology, Emily J. Blasingham, Loyola University; Bacteriology, Morris Wagner, University of Notre Dame; Botany, C. Franklin Bishop, Goshen College; Chemistry, Robert E. Davis, Purdue University; Ecology, Donald E. Miller, Ball State University; Entomology, Ray T. Everly, Purdue University; Geology and Geography, Lee Guernsey, Indiana State University; History of Science, Lawrence H. Baldinger, University of Notre Dame; Physics, Robert Wise, Purdue University (Fort Wayne); Plant Taxonomy, Jack Humbles; Soil Science, James M. Smith, Anderson College; Zoology, Russell E. Mumford, Purdue University.

The following slate of officers and committees to be elected by The Academy for 1966 was presented by Dr. Harry G. Day, the Nomination Committee chairman: President, Carrolle A. Markle, Earlham College (as 1965 President-Elect accedes Presidency according to the Constitution); President-Elect, Alton A. Lindsey, Purdue University; Secretary, Clarence F. Dineen, Saint Mary's College; Treasurer, Frank Guthrie, Rose Polytechnic Institute; Editor, William R. Eberly, Manchester College; Director of Public Relations, James Clark, State Entomology Department; Trustee Academy Foundation, William A. Daily, Eli Lilly and Company (1967); Bonding Committee, Donald J. Cook, DePauw University, and R. M. Brooker, Indiana Central College; Research Grants Committee, Winona H. Welch, DePauw University (1970), and H. H. Michaud, Purdue University (1968). Howard H. Michaud was elected to replace Dr. A. A. Lindsey (President-Elect). Special nomination: Richard A. Laubengayer (retiring editor) as Honorary President. A motion was carried to cast a unanimous ballot for the slate of officers and committee members.

President Frank J. Welcher presented a scholarly address entitled, "Metal Chelates." The address is printed elsewhere in the Proceedings of the Indiana Academy of Science.

The meeting was adjourned at 9:30 p.m.

CLARENCE F. DINEEN, Secretary

FINANCIAL REPORT OF THE INDIANA ACADEMY OF SCIENCE

January 1, 1965 through December 31, 1965

	Jan. 1, 1965 Balance	*Receipts*	*Disbursed*	*Dec. 31, 1965 Balance*
1. Academy Proper	801.10	4,918.38	3,057.83	2,661.65
2. Academy Funds for Research	802.00	350.00	150.00	1,002.00
3. J. S. Wright Memorial Library and Lilly Endowment	721.95	0.00	570.90	151.05
4. Lilly Endowment Grant II	0.00	5,300.00	2,548.98	2,751.02
5. Science Fair	3,102.40	0.00	1,422.99	1,679.41
6. Science Talent Search	1,811.38	2,000.00	1,445.61	2,365.77
Total in State Accounts	7,238.83	12,568.38	9,195.31	10,610.90
N.S.F. Grant GE 4306	4,493.94	5,000.00	9,493.94	0.00
N.S.F. Grant GE 9588	0.00	5,968.15	2,848.79	3,119.36
Total in all Academy accounts	11,732.77	23,536.53	21,539.04	13,730.26

Bank balances, American National Bank & Trust Company, Muncie, Indiana

Checking Account	2,607.18
Savings Account	11,123.08
	13,730.26

Signed James C. List
James C. List
Treasurer
December 31, 1965

April 13, 1966

We the undersigned have audited the treasurer's books of the Indiana Academy of Science for the year 1965 and have found everything in good order.

William W. Bloom
Robert J. Hanson

NEW MEMBERS—1965

Adelaide, Sister Mary, Marian College, Indianapolis, Ind.	Bo
Albright, Dr. Jack Lawrence, Dept. of Animal Sciences, Purdue University, Lafayette, Ind.	Z
Antonis, Miss Aliki, 416 W. Marion St., South Bend, Ind. 46601	Bo
Barter, Mr. David Henry, 2645 Hulman St., Terre Haute, Ind.	G
Beesley, Mr. and Mrs. Lloyd, R. R. 1, Box 106, Cedar Grove, Ind.	Bo
Bell, Mr. Henry L., 403½ E. Third St., North Manchester, Ind. 46962	Z
Brown, Dr. Mary J., 3111 East St. Joseph St., Indianapolis, Ind. 46201	Z
Clark, Donald L., R. R. 1, West Baden, Ind.	M, Ph
Clifford, Brian Curtis, Dept. of Botany and Plant Pathology, Lilly Hall, Purdue University, Lafayette, Ind.	Bo
Coartney, James S., Dept. of Botany and Plant Pathology, Purdue University, Lafayette, Ind.	Bo
Coburn, Dr. Stephen P., 3808 Knollcrest Road, Fort Wayne, Ind.	C
Conrad, Miss Phyllis, Dept. of Botany and Plant Pathology, Purdue University, Lafayette, Ind.	Bo
Davis, Mr. John V., 52149 Helman Rd., South Bend, Ind. 46637	Bo, Z
Demaree, Richard S., Jr., 100 Farrington St., Apt. 213, Terre Haute, Ind.	Z
Dhonau, Dr. C. A., Vincennes University, Vincennes, Ind.	C
Dybel, Michael W., 2907 Strong Street, Highland, Ind.	C
Eisinger, William, Dept. of Botany and Plant Pathology, Purdue University, Lafayette, Ind.	Bo
Ellingson, Dr. R. C., Research Center, Mead Johnson & Co., Evansville, Ind. 47721	C
Eliel, Prof. Ernest L., Dept. of Chemistry, University of Notre Dame, Notre Dame, Ind.	C
Everly, Melvin Eugene, 243 West Graham Ave., Lombard, Ill.	Z
Foster, Miss Janice C., 318 Waldron Street, West Lafayette, Ind.	E
Gates, Dr. Louise W., 109-C English Bldg., Ball State University, Muncie, Ind.	Ps
Gilbert, Dr. Scott K., Pride Company, Inc., Glen Haven, Wis.	Bo
Grant, Kenneth E., 311 W. Washington St., Room 212, Indianapolis, Ind. 46240	SS
Hall, Miss Dawn, 127 North 2nd West, Brigham City, Utah	Bo
Horowitz, Dr. Alan Stanley, Geology Dept., Indiana University, Bloomington, Ind.	G
Huffman, Mr. and Mrs. John Curtis, University Apts. W-303, Bloomington, Ind.	C

Jacobs, Merle E., Goshen College, Goshen, Ind. 46526	Z
Johnson, Mr. Gerald Homer, 412 Campus View Apts., Bloomington, Ind.	G
Jones, Daniel David, Dept. of Botany and Plant Pathology, Purdue University, Lafayette, Ind.	Bo
Keller, Dr. M. Wiles, 518 Carrolton Blvd., W. Lafayette, Ind.	M
Kline, Dr. Richard M., Eli Lilly & Co., Research Labs, Greenfield, Ind.	Ba
Lair, Mr. Ben, Geography Dept., Valparaiso University, Valparaiso, Ind.	G
Lee, Howard Wm., Indiana Geological Survey, Bloomington, Ind.	G
Leman, Samuel E., 621 W. Plymouth St., Bremen, Ind.	C
Lorentzen, Dr. Keith E., Indiana University, Northwest Campus, 3400 Broadway, Gary, Ind.	C
Manalis, Richard S., Dept. of Anatomy and Physiology, Indiana University, Bloomington, Ind.	Z
Medvick, Mr. Charles, P. O. Box 210, Terre Haute, Ind. 47808	SS
Meyer, Frederick R., Dept. of Anatomy and Physiology, Indiana University, Bloomington, Ind.	Z
Miranda, Dr. Thomas J., 16731 Brick Road, Granger, Ind.	C
Mollenhauer, Dr. Hilton H., Charles Kettering Research Lab, Yellow Springs, Ohio	Bo
Morré, Dr. D. James, Dept. of Botany and Plant Pathology, Purdue University, Lafayette, Ind.	Bo
Mulcare, Donald J., Dept. of Biology, University of Notre Dame, Notre Dame, Ind.	Z
Mussell, Harry W., Dept. of Botany, Purdue University, Lafayette, Ind.	Bo
Myers, Dr. Ruth L., 109-A English Bldg., Ball State University, Muncie, Ind.	Ps
Olson, Dr. J. Bennet, Biological Sciences, Purdue University, West Lafayette, Ind.	H
Palmer, Arthur N., Dept. of Geology, Indiana University, Bloomington, Ind.	G, SS
Pasto, Prof. Daniel J., Dept. of Chemistry, University of Notre Dame, Notre Dame, Ind.	C
Pettersen, Mrs. Mary J., 6920 Kennedy Ave., Hammond, Ind.	Bo, C
Piwonka, Robert W., Dept. of Anatomy and Physiology, Indiana University, Bloomington, Ind.	Z
Reshkin, Mr. Mark, Indiana University Northwest Campus, Gary, Ind. 46408	G
Santos, Dr. John F., Dept. of Psychology, University of Notre Dame, Notre Dame, Ind. 46556	Ps
Savage, Dr. Earl John, Dept. of Biology, University of Notre Dame, Notre Dame, Ind.	Bo

Souder, Donald L., Dept. of Anthropology, Indiana University, Bloomington, Ind.	A
Souers, Charles V., 2552 E. 8th St., Bloomington, Ind.	Ba
Stucky, Billie W., 111 S. Bryan Ave., Bloomington, Ind.	Bo, Z
Sulzbach, Mary Diane, Cascade Terrace, Burlington, Iowa	E
Thaeler, Dr. Charles S., Jr., Indiana University, South Bend Campus, South Bend, Ind.	Z
Tieken, Al J., Box 63, Haubstadt, Ind.	Z
Wagner, Morris, Lobund Laboratory, Notre Dame, Ind.	Ba
Walton, George W., R. 1, Farmersburg, Ind.	Ph
Wence, Ronald Lee, 2901 Ronan St., Apt. 4, Midland, Mich. 48642	C
Winters, John L., Jr., 406 Conduitt Dr., Mooresville, Ind.	PT

INDIANA JUNIOR ACADEMY OF SCIENCE
THIRTY-THIRD ANNUAL MEETING

OFFICERS

President: John Darsee, John Adams High School, South Bend
Vice President: Ed Emery, New Albany High School, New Albany
Secretary: Micky O'Leary, Reitz Memorial High School, Evansville

COUNCIL

Dr. Howard Michaud, Chairman, Department of Forestry and Conservation, Purdue; Miss Helen Reed (1962-1966), Manual High School, Indianapolis; Mr. Erwin Steinkamp (1963-1967), New Albany High School, New Albany; Sister Marian Francis (1964-1968), Reitz Memorial High School, Evansville; Mr. Keith Hunnings (1965-1969), New Haven Senior High School, New Haven

YOUTH ACTIVITIES COMMITTEE

Prof. Virgil Heniser, Chairman, Coordinator for School Science, Morrison Hall 108, Indiana University, Bloomington, Indiana 47405.

DIRECTOR

Prof. Donald R. Winslow, Science Department, Division of University Schools, Bloomington, Indiana 47405

PROGRAM

October 9, 1965

8:30 A.M.—10:00 A.M.:

Registration and Election of Officers in the Rathskeller of the La Fortune Student Center, Bldg. 43. Club representatives may file their ballots with the Junior Academy Council representative.

9:30 A.M.—12:00 Noon:

Junior Academy Council Interviews for "Best Boy" and "Best Girl" Awards. Room 239, Nieuwland Science Hall, Bldg. 52. Interviewees will register at room 239.

10:00 A.M.—12:00 Noon:

Tours. Rathskeller of the LaFortune Student Center, Bldg. 43.

11:30 A.M.—1:00 P.M.:

Lunch. Cafeteria, South Dining Hall, Bldg. 16, or The Huddle, Bldg. 43.

1:30 P.M.—3:30 P.M.:

Annual business meeting. John Darsee, President, presiding. Engineering Building Auditorium, Bldg. 40.

Greetings. Mr. Ernest Litweiler, John Adams High School, South Bend.

Program of Papers:

1. The Use of Chromatography in the Detection of Amino Acids. James Gruver, IONS, Riley High School, South Bend.
2. The Effect of Atmospheric Conditions in Indianapolis on Airborne Microbial Flora. Lynette Woods, Science Club, George Washington High School, Indianapolis.
3. A Variation of the Classic Auxin Experiment. Betty Sue Settle, Portland Junior High School Science and Math Club, Portland.
4. The Effects of Electricity, Magnetism, and Light on the Growth and Pigment Production of Two Molds. Suzanne Bartlett, E. Wayne Gross Academy, University Schools, Bloomington.
5. The Research and Development of a Practical X-Ray Machine for the Amateur Physicist. Mark E. Wyss, Brebeuf Science Club, Brebeuf Preparatory School, Indianapolis.
6. Bioelectricity. Hugh Hanlin, Junior High School Science and Math Club, Portland.
7. Nuclear Magnetic Resonance. Mary Lancaster, Sigma Mu, Franklin Central High School, Acton.
8. The S.C.S. and its Two-Transistor Analogy. James Spreen, Phi Chi Science Club, New Haven High School, New Haven.
9. Construction and Operation of a Gas Laser. Robley Evans, Portland Senior High School Science and Mathematics Club, Portland High School, Portland.
10. Is the Entire Gastrovascular Cavity Essential for Digestion in the Hydra? Kathleen Gibson, IONS, Riley High School, South Bend.
11. The Effect of Cations on Amino Acid Polymerization in the Rabbit Reticulocyte. Gordon B. Linn, Sigma Mu, Franklin Central High School, Acton.
12. A Supplement to Deam's **Flora of Indiana.** Malinda Finch, Portland Senior High School Science and Mathematics Club, Portland High School, Portland.
13. A Comparison Study of the Lands. Lauren Baldea, Biology Club, Lew Wallace High School, Gary.
14. The Effect of Clouds upon Solar Radiation. J. D. Ellis, E. Wayne Gross Academy, University Schools, Bloomington.
15. The Validity of the Presence of Visual Pigment in Ungulates. Louise Kelty, Phi Chi Club, New Haven Senior High School, New Haven.
16. Experiments to Determine the Function of the Thyroid in its Effect on the Interrelationship between the Basal Metabolic Rate and Cardiovascular Activity of *Rana pipiens.* John Darsee, Junior Izaak Walton League, Adams High School, South Bend.

Presentation of Charters.
Presentation of new officers.
Presentation of Junior Academy Council and special guests.
Presentation of awards.
Adjournment.

MINUTES

The thirty-third annual meeting of the Indiana Junior Academy of Science was held on Saturday, October 9, 1965, on the campus of Notre Dame University, South Bend, Indiana. The President, John Darsee, opened the meeting and introduced the host, Mr. Litweiler, who briefly welcomed all members, sponsors, and guests to the meeting.

In the absence of Mickey O'Leary, secretary, John introduced Carolyn Hacker, secretary pro tem, who read the minutes of the thirty-second annual meeting of the Junior Academy. No additions or corrections were offered and the minutes were approved as they were read.

Following the reading of the minutes was the presentation of papers. A total of sixteen papers, as listed in the program, covering varied student projects were heard.

President John Darsee then presented Mr. Winslow, director of the Junior Academy of Science. Mr. Winslow thanked Mr. Litweiler for acting as host and then presented charters for new clubs. Mr. Winslow told the Academy that next year's meeting (1966) would be held at Fort Wayne, at Wabash in 1967, and Ball State in 1968. Mr. Winslow made an appeal to all members, sponsors, and guests present to bring forward to him any suggestions for the improvement of next year's program.

Mr. Winslow then announced the new officers for next year's Academy. They are: President, James Spreen of New Haven; Vice President, Dennis Waltke of University School, Bloomington; Secretary, Mary Ellen Lancaster, Franklin Central High School, Acton.

The meeting then was turned over to Miss Helen Reed, senior member of the Council, who announced the winners for "Best Boy" and "Best Girl" in science. She explained that this award is given to a boy and girl who has done outstanding and extensive work in science. The "Best Boy" in science for 1965 was John Darsee, Adams High School, South Bend. The "Best Girl" in science for 1965 was Mary Ellen Lancaster, of the Sigma Mu Club, Franklin Central High School. Suzanne Bartlett, University High School, Bloomington, received an award for outstanding work in the field of microbiology from the Indiana Branch of the American Society for Microbiology.

Professor Winslow then made a few concluding remarks in which he stated that Mr. Hunnings of New Haven would be the host for the Junior Academy for next year.

Two hundred three students and twenty seven sponsors registered for the meeting.

President John Darsee adjourned the meeting at 3:20 p.m.

Respectfully submitted,
CAROLYN HACKER, Secretary pro tem

INDIANA JUNIOR ACADEMY OF SCIENCE

1964-1965

Town	*Club and School*	*Sponsor*
Acton	Sigma Mu Chapter of FSA, Franklin Central H. S.	Allan Morgan
Bedford	Bedford Science Problems Research Group, Bedford H. S.	Paul Hardwick
Bloomington	National Scientific Honor Society, Bloomington H. S.	Orville Long
Bloomington	E. Wayne Gross Academy, University H. S.	Billie Stucky
Bloomington	Albert Schweitzer Academy, University Junior High	Elliott Koyanagi
Bloomington	H. J. Muller Academy, University Junior High	Lew E. Wise
Bloomington	MSE Academy, University Junior High	Charles Souers
Columbus	Science Club, Columbus Senior H. S.	L. N. Carmichael
Crawfordsville	Up-N-Atom, Crawfordsville, H. S.	David Wells
Evansville	Reitz Memorial Chapter of FSA, Reitz Memorial H. S.	Sr. Marian Francis
Fort Wayne	Albertus Magnus Science Club, Central Catholic H. S.	Sr. Winifred
Fort Wayne	Phy-Chem Club, Elmhurst H. S.	Ruth Wimmer
French Lick	Springs Valley Science Club, Springs Valley H. S.	D. L. Clark
Gary	Biology Club, Lew Wallace H. S.	Lola Lemon
Griffith	Griffith Junior High Science Club, Griffith Junior H. S.	Fred Meeker
Hammond	Chemistry Club, Oliver P. Morton H. S.	Mary J. Pettersen
Hartford City	Hartford City H. S. Science Club, Hartford City H. S.	F. Ray Saxman
Highland	Science Club, Highland H. S.	Jon Hendrix
Huntington	Aristotelian, Huntington Catholic H. S.	Sr. M. Petrona
Huntington	Science, Huntington H. S.	Robert Diffenbaugh
Indianapolis	Arlington Science Club, Arlington H. S.	David Blase
Indianapolis	Nature Club, Arsenal Technical H. S.	Michael Simmons

Town	*Club and School*	*Sponsor*
Indianapolis	Brebeuf Science Club, Brebeuf Preparatory School	Rev. Richard J. Middendorf, S.J.
Indianapolis	Science Club, Howe H. S.	Miss Jerry Motley
Indianapolis	Manual H. S. Science Club, Manual H. S.	Wayne E. Dunbar David Otto
Indianapolis	North Central H. S. Science Clubs, North Central H. S.	Robert Prettyman
Indianapolis	Science Club, George Washington H. S.	Mrs. E. H. Crider
Indianapolis	Science Club of Westlane, Westlane Junior H. S.	John Van Sickle
Jamestown	Science Club of Granville Wells, Granville Wells School	Cecil O. Bennington
La Porte	Bi-Phi-Chem Club, La Porte H. S.	Frances M. Gourley Byron Bernard
Lebanon	Junior Explorers of Science, Lebanon Junior H. S.	Tom Ewing
Madison	Madison Science Club, Madison Consolidated H. S.	David Dunkerton Walter A. Corey, Jr.
New Albany	Science Club, New Albany Senior H. S.	Erwin Steinkamp
New Haven	New Haven Science Club, New Haven H. S.	Keith Hunnings
Portland	Portland Senior H. S. Science and Mathematics Club, Portland Senior H. S.	Ralph Settle Robert Freemyer
Portland	Science Club, Portland-Wayne Township Junior H. S.	Bill Norris
South Bend	Junior Izaak Walton League, John Adams H. S.	Ernest Litweiler
South Bend	JETS Junior Engineering Technical Society, Central H. S.	Lawrence K. Cox
South Bend	Second Year Biology Class, Clay H. S.	John V. Davis
South Bend	IONS Club, J. W. Riley H. S.	John Marker
Terre Haute	Pius X Science Teens, Schulte H. S.	Sr. Thomas Mary
Vincennes	Sigma Tau Science Club, Saint Rose Academy	Sr. Suzanne

NECROLOGY

Fay Kenoyer Daily, Butler University

John June Davis

Centralia, Illinois	Bethel Park, Pennsylvania
October 9, 1885	July 13, 1965

Realizing the increasing importance of the many new pesticides and their uses, John June Davis organized at Purdue University the first Pest Control Operator's Conference and the first four-year course for pest control operators. For his important work in this field, he gained the affectionate title of "Professor of Pest Control" (Indiana Business and Industry, Sept., 1957). In addition to administration and his courses at Purdue, Prof. Davis addressed national and regional pest control associations, wrote many popular and scientific articles on economic entomology and a book in 1928 on **Common Garden Pests.** He traveled widely over Europe and this country following entomological interests.

Born in Centralia, Illinois, in 1885, J. J. Davis received a B.S. degree at Illinois, 1907, was assistant to the State Entomologist in Illinois from 1907 to 1911 and was charter member of the Illinois Academy of Science.

He first came to Indiana to be in charge of the laboratory of the U. S. Department of Agriculture, Lafayette, Indiana, 1911, and held this post until 1919. He was on a Japanese beetle control project at Riverton, N. Y., from 1919 to 1920, but came back to Indiana in 1920 to be head of the Entomology Department at Purdue University. There his interests included besides economic entomology, specialization in the study of Aphididae, Phyllophaga, the Japanese beetle and the European corn borer. He retired from the Entomology Department at Purdue in 1956 after a distinguished career as head of the department for 36 years. He was granted a Professor Emeritus status at Purdue and devoted himself to pest control research and counsel.

As our secretary, Dr. Dineen, so aptly stated in a letter, "the Academy is indebted to members of the quality of Dr. Davis." He has an outstanding record of service to the Indiana Academy of Science as Editor from 1922 to 1928, President in 1931, member of standing committees, chairman of the Division of Entomology, and contributor of many papers to his section's programs. He was made a Fellow in the Indiana Academy of Science in 1924 as a recognition of achievement and service to the Academy. His reports on insects of Indiana presented at the Entomology Division meetings spanned many years. In a day when we seem to hear less and less about the very important functions of local scientific organizations, J. J. Davis in a timely article (Proc. I.A.S., 1960) outlined the role of Entomology in the Indiana Academy of Science and reflected on its purposes. The chief purposes of the Academy were given as "to stimulate interest in the scientific problems

JOHN JUNE DAVIS

of the area, together with a stimulation for investigation and research in general."

Other affiliations were Phi Chi Omega, professional fraternity; honorary member of the National Pest Control Association; Alpha Zeta, honorary agricultural fraternity; Treasurer and Editor of the Say Foundation; Fellow, Fruit Fly Board; Fellow, A.A.A.S.; honorary member of the Entomological Society (secretary-treasurer, 1926-1931, president, 1932); Association of Economic Entomology (vice-president, 1935, president, 1938); member of the Central Presbyterian Church and the Masons. He is listed in **American Men of Science** and **Indiana Scientists.**

John June Davis, internationally known entomologist and author, died unexpectedly at 79 years of age, July 13, 1965, in Bethel Park, Pennsylvania, while visiting relatives. He was brought home to Lafayette, Indiana, for funeral services held July 17, 1965.

PRESIDENTIAL ADDRESS

Metal Chelates

Frank J. Welcher, Indiana University, Indianapolis Downtown Campus

During the second half of the nineteenth century chemists recognized that many of the substances then known could not be fitted in to the ideas of valency which had previously been developed. For example, metals were found to form compounds, often with stable molecules, in which the metal exhibited a valency which was greater than the oxidation state (or valency) which was the basis for the theory then in vogue. A typical example of this was the reaction of copper sulfate in aqueous solution with ammonia to yield a dark blue solution, which upon crystallization yielded a substance which proved to be $Cu(NH_3)_4SO_4$, and not $CuSO_4$. Similarly, cobalt, platinum, zinc, and a number of other metals were found to yield similar complexes with ammonia. A number of theories were proposed to account for the existence of such compounds, but it was not until Werner (21) in 1893 proposed his now-famous coordination theory. Essentially, his theory contained the following postulates: (a) there are two types of valence, one of which is now called ionic valence, and the other coordinate valence; (b) for each central ion there is a fixed number of coordinate valences called the coordination number; (c) coordinate bonds may be formed by a metallic ion with either ions or molecules; and, (d) coordinate groups have a definite spatial arrangement about the central atom. The latter has proved to be a very significant part of the theory. In 1904 Ley (13) first studied the compound formed in the reaction of the copper (II) ion with glycine, or aminoacetic acid, $H_2N\text{-}CH_2\text{-}COOH$. As a result of these investigations, Ley found that the copper (II) ion combines with two molecules of glycine. Further, he learned from conductance measurements that the copper is no longer ionic, which indicated that bonding was not due to ordinary ionic bonding. It is now known that the copper atom is a part of a ring structure involving both glycine molecules. Through the amino and carboxyl groups, glycine occupies two positions in what is known as the coordinations sphere of the copper atom. A compound of this type is known as a **chelate** compound. The term chelate was proposed by Morgan (15) to designate those cyclic structures which arise from the union of metallic atoms with organic or inorganic molecules or ions. The name is derived from the Greek word *chela*, which means the claw of a lobster or crab. This term is used to indicate symbolically the manner in which the chelating group attaches to the central atom.

When a metal ion combines with an electron donor, the resulting compound is said to be a complex or coordination compound. If the substance which combines with the metal contains two or more donor groups, so that one or more rings are formed, the resulting compound is said to be a chelate, and the donor structure is called the chelating agent. The electron pair bonds formed between the metal and the donor groups may be essentially ionic or essentially covalent, depending on the nature of the metal and the donor group involved. In general, in the following discussion, it is unnecessary to consider the nature of the bonds that are formed, but only to note the types and stabilities of the structures involved.

Some of the chemical and physical properties of metal chelates resemble those of simple complexes and differ only in a quantitative way. On the other hand, some properties are fundamentally different, and chelate compounds may properly be considered as a distinct class of compound with characteristic behavior. Among the more distinctive properties of this class of compounds are the following:

(a) They are generally insoluble in water.
(b) They are usually soluble in non-polar liquids.
(c) Many are extremely stable. For example, some of the metal chelates formed with acetylacetone may be volatilized without decomposition.
(d) Many chelates are highly colored and usually have a color different from that of the normal salts of the metals involved.
(e) Many chelating agents react in a specific or selective manner with only a few ions.

It is difficult to over-emphasize the importance of metal chelates in various branches of theoretical and applied chemistry and allied fields. One of the earliest of the recognized potential applications of chelating reagents was in qualitative and quantitative analysis. Reagents, such as dimethylglyoxime, which is essentially specific for the nickel ion, have contributed greatly to the elimination of interference in analytical procedures. Other reagents form such highly colored complexes that as little as 0.001 μg. of metals can be detected and determined with their use. The development of the theory of chelation provided a foundation for new developments in the field of colored lakes, such as, for example, the alizarin lakes and the chrome lakes of *o.o'*-dihydroxyazo compounds. Chelates have found useful application in physiological chemistry, and many important medicinal products have been developed. Blood pigment, chlorophyll, and cytochrome are interesting chelates which are indispensible for life processes. Certain metal chelate pigments, such as phthalocyanines, are now widely used. Recently a rather large class of new aminopolycarboxylic acids, which have the unusual property of forming water-soluble chelates, have been of remarkable application. Some of these such as ethylenediaminetetraacetic acid and condensed phosphates are now being manufactured in very large quantities and are used for numerous purposes wherever the removal of metallic ions is desirable, such as in water softening, as negative catalysts, and in the clarification of solutions.

Special methods for the purification and separation of metals have been developed which are based upon the high volatility and also the solubility of metal chelates in non-polar solvents. The use of chelating agents in connection with cation exchange resins and solvent extraction have also proved very important in the separation of radio-active metals.

These and many other applications, such as germicides, decontaminations, metal buffers, and many phases of agriculture have combined to make these substances among the more interesting developed in recent years.

Most of the more important applications of chelates depend upon the selective or specific action between the chelating agent or ligand and metal ion or ions, and also upon the control of the concentration of metal ions in a given medium. Both effects are related to the strength of the bonds formed between the ligand and the metal. Consequently, a fundamental understanding of the applications of chelate systems requires an understanding of those factors which effect chelate stability. This, of course, is a long and complex subject, and only the very briefest outline will be presented here. This is considered important in more detailed studies because most chelating agents are organic molecules, and the number of these which have been prepared or which are potentially possible is enormously large. Consequently, the selection of existing compounds, the design of new compounds, and an understanding of natural chelate functions are all facilitated by an understanding of the relationship between ligand structure, the nature of the metal, and the resulting stability of the chelate which they form.

Factors Affecting Chelate Stability

The stability of a metal chelate, that is, the strength of the bond between the metal and ligand atom, is determined by the following:

(a) The nature of the metal atom.

(b) The size of the ring structure formed. This depends upon the location of the acidic and/or coordinating groups in the ligand molecule. The most stable chelates contain saturated ligands that form 5-membered rings, and unsaturated ligands which form 6-membered rings.

(c) The number of rings. In general a metal chelate is more stable than an analogous non-chelate complex. This enhanced stability is referred to as the chelate effect. For example the nickel complex with ethylenediamine, which is a chelate, is more stable than the hexammine complex of nickel, which is not. Further, the more extensive the chelation, the more stable the system. Thus, for example, a molecule such as ammonia which can be attached at only one point is referred to as a unidentate ligand. A molecule such as glycine which has two groups that are capable of linking to a metal atom is referred to as a bidentate ligand, and is, of course, capable of chelate formation. Other molecules may contain three, four, five, six, or even more donor groups and are thereby capable of forming structures having more than one ring. In general, the more rings the chelating agent can form, the more stable is the resulting chelate. It must be emphasized, however, that ligands of entirely different chemical structure may result in chelates of widely different stability.

(d) Base strength of ligand. As a rule, the greater the base strength of the ligand the greater is its tendency to form a stable complex. Other factors, however, may out-weigh base strength. It is of interest at this point to note that various substituent groups in organic molecules may have important effect on base strength, and in this way the controlled modification of the strength of chelate structures becomes possible.

(e) Resonance. The stability of a chelate ring is affected by the presence or absence of resonating structures. Consequently, ligands having the necessary resonating structures may form more stable chelates than those that do not.

(f) Steric factors. The actual size and spatial distribution of the various parts of the ligand molecule are often very significant in determining the stability of the chelate which it forms. In general, large and bulky ligands form less stable metal complexes than do analogous smaller ligands. Further, certain groups may be attached in such positions as to interfere with the coordination process, or interfere with the assumption of the necessary spatial configurations to make possible a stable chelate. It is in this connection, that some of the most interesting applications of the development of specific analytical reagents have derived.

Metal Chelates in Biological Systems

Although in one form or another the chemistry of metal chelates has touched upon almost every field of chemistry, a number of illustrative examples of their significance which are presented here have largely been drawn from the field of biochemistry.

Metal buffers. It was mentioned earlier that a carefully regulated control of the concentration of metal ions in solution, that is, as metal buffers, is provided by chelate compounds. Metal buffers are analogous in their action to pH buffers in that they provide a fairly constant concentration of the metal ion. An example of the use of chelating agents as metal buffers is provided by the behavior of algae with chelated copper. Algae are very susceptible to an exact concentration of copper in solution. In the complete absence of copper, these organisms suffer deficiency symptoms. It is well known that the presence of large amounts of copper in water is a normal method for the destruction of algae. It appears that algae can thrive on a very low concentration of copper, provided that it is constantly renewable. This can be provided by the equilibrium concentration of copper in a chelate solution. Studies have shown that the optimum concentration of copper for algae is so low that if provided by a normal salt, such as copper sulfate, either the concentration is just suitable, and hence rapidly exhausted, since there is no reservoir; or, if there is sufficient copper that it will not be rapidly exhausted, then it is too high for healthy growth. Only in the form of a chelate can it be both fully available, and yet never present in too high a concentration. In this connection it should be clear, that copper chelates are quite ineffective in controlling aquatic weeds. Metal chelates have also been used in the nutrition of microorganisms to maintain trace amounts of metals at low nontoxic concentrations and to provide a reservoir for the metal in nutrient media.

Trace Elements. Thirty-eight elements have been detected in biological systems, and approximately fifteen of these are known to be required by both plants and animals. In plants trace amounts of zinc, manganese, molybdenum, copper, cobalt, and perhaps vanadium are required. Since iron is frequently unavailable to plants, even when present in soils in moderately large amounts, and since iron deficiency leads to serious effects in plants, iron is usually included with essential trace elements. Others may be aluminum, barium, and boron, and in animals also cobalt, fluorine, and iodine. The over-all essential elements for both plants and animals include the following: iron, manganese, zinc, copper, cobalt, boron, molybdenum, vanadium, iron, and iodine.

Biological functions of trace metals. Trace metals appear to be essential for the formation and functioning of many enzymes (20). Studies indicate that the site of reactivity of enzyme and substrate is the metal itself. Many naturally occurring chelates in biological systems have functions vital to the organism. These include the catalysis of redox reactions; oxygen-carrying powers; hydrolysis and synthesis of proteins; decarboxylation and carbon dioxide-carrying power; and in addition many others that are less familiar.

Among the more familiar chelates in biological systems are the prosthetic groups of hemoglobin and of chlorophyll. These are porphin derivatives, and include such well-known catalysts as cytochromes, catalases and peroxidases. These also appear in Vitamin B_{12}, which contains a cobalt (III) porphyrin chelate, and seems to function as part of an enzyme system (2).

Hemoglobin is an iron(II) porphin derivative with an enzyme-like function of oxygen storage and transport. This is probably due to the bonding of oxygen to the iron atom in the chelate. The oxygen-binding function of hemoglobin can be completely blocked by any group which forms a stronger bond with iron than does oxygen, which is the substate in this case. For example, the oxygen-binding function is completely destroyed by both carbon monoxide and the cyanide ion, which form very strong bonds with iron.

It was mentioned earlier that the bonding in coordination compounds usually occurs in definite spatial patterns. In this connection it is interesting to note that in biological syntheses metal ions appear to exercise directive effects which lead to what might be called programming in the joining together of certain organic structures. The phosphatase enzymes afford an example of interest in this connection. Almost every phosphatase that has been studied in detail has been found to require either magnesium or manganese for maximum activity. The following possible explanation has been offered: All enzymes which involve phosphate transfer of one sort or another participates in the action of one of a group of coenzymes, all of which contain a pyrophosphate or a diphosphate group. Such groups form chelates with metal ions. Thus, it is logical to assume that enzymes and coenzymes are probably brought together by simultaneous combination with the metal ion. This apears to apply to such coenzymes as ATP (adenosine triphosphate; ADP (adenosine diphosphate); DPN (diphosphoropyridine nucleotide); TPN (triphosphoropyridine nucleotide); and CoA (coenzyme A (1).

A further interesting example of the directive effect of a metal ion in biological syntheses is the role of iron in the formation of chlorophyll (18). One of the essential functions of iron in plants, and perhaps its most essential function, is the catalytic role in the synthesis of chlorophyll. The chemistry of this reaction is complex, but iron (III) ion appears to act as an organizer for the combination of the pyrrole groups to bring them into proper position to form uroporphyrin. Thus the coordinate bonds of iron serve to hold the porphobilinogen groups in the correct position for condensation to a cyclic porphyrin rather than in a random linear fashion. It is of further interest that chlorophyll is not an iron chelate, but in some manner magnesium displaces iron once the porphin structure has been formed. The iron forms a stronger bond with the ligand, but possibly the iron atom passes on in the formation of a new stable porphin ring and is replaced by magnesium.

Carriers of trace metals in soils. A number of anions commonly occurring in the aqueous systems of plants and animals, as well as in soils, form stable, soluble chelates with trace metals. Among the more common of these are citrate, tartrate, malate, and the anions of the amino acids. Roots of plants secrete and release small amounts of organic acids which solubilize and transport trace metals. The exact nature of these is not known, but almost certainly they are chelating agents, and are probably hydroxy acids or amino acids. If all the metal content in soil were present in the dissolved state, as, for example, a chelate, it would rapidly be leached into the subsoil and lost. Some metal is present absorbed on the surface of cation-exchange components of soils, such as humic acids, clays, and similar macromolecular structures, and may readily be removed to a solution phase by natural or synthetic chelating agents. Most metals in soil, however, are locked in the mineral portion in the form of insoluble inorganic salts such as silicates, phosphates, aluminates, carbonates, and sulfates. These are released by decomposition of rock structure and the metal slowly is converted into soluble form such as bicarbonates and chelates.

Carriers of trace metals in physiological systems. The physiological pH is sufficiently high to convert heavy metals completely to insoluble hydrolysis products. Therefore, no appreciable concentration of trace metal ions can be present in animal systems. A number of hydroxy acids are present, however, which form chelates, and can be considered as carriers for trace metals. The anions of such hydroxy acids are citrate, lactate, and malate (9). Heavy metals, including lead and mercury, which have no essential biological function can combine quickly with serum proteins to form complexes of considerable stability. Most metals, except sodium, potassium, calcium, and magnesium, are believed to be transported in blood serum as protein complexes, although these are actually colloidal.

Use of Synthetic Chelates in Biological Systems

The addition of unnatural chelating agents may produce profound effects on biological systems. Such substances may inhibit, partially or completely, a metal-enzyme function if powerful enough to compete for the metal. If the enzyme is essential to the functioning of the organism, death may result, or the organism otherwise weakened. This principle is used in bactericidal and fungicidal action.

Antibacterial substances. Various studies have revealed interesting correlations between chelation and antibacterial properties. For example, of all the monohydroxyquinolines, only 8-hydroxyquinoline shows any bacterial activity, and this the only one capable of forming metal chelates. Further, the substitution of some inert groups, that is some group presumably not affecting chelation, in some cases adversely affects activity, and in some cases results in no effect at all. Thus, in 2-methyl-8-hydroxyquinoline the activity is greatly reduced. 5-Methyl-8-hydroxyquinoline, on the other hand, has the same order of activity as 8-hydroxyquinoline. The 2-position is known to inhibit chelation, either because of steric effects or because of its effect on the basicity of the ligand, and accordingly it may be presumed that the relationship between 2-position substitution of the methyl group and antibacterial activity are dependent on chelate formation (14).

Iron chelates in plant nutrition. Iron deficiency has been observed in soils of almost all parts of the United States. Frequently soil contains iron, but in many cases it is unavailable to plants. This may be the result of pH or other soil characteristics which render iron compounds too insoluble for absorption by plants. Under these conditions the use of synthetic chelating agents as carriers for iron has been indicated. Satisfactory reagents for this purpose should have sufficient iron chelate stability to prevent the formation of insoluble salts, but on the other hand they should not be so stable as to prevent the metal from being released to the plant. In recent years a number of experiments have been carried out on the use of various chelating agents to alleviate iron chlorosis. The work of Stewart, Leonard, and coworkers (19, 16, 12, 1) has yielded spectacular results in the treatment of iron chlorosis of citrus trees growing in the acid aerated soils of Florida through the use of iron chelates of some of the aminopolycarboxcyclic acids and other materials. These soils are sandy in nature, and of low organic content, and considerable amounts of oxygen are present. Although iron is usually present in quantities sufficient for most plants, the concentration of natural carriers is very low in view of the small amount of organic material present. Under these conditions the iron is completely hydrolyzed either to the hydroxide or to a basic salt. Ethylenediaminetetraacetic acid forms an iron(III) chelate which is quite stable in mildly acidic solutions. The influence of this chelate in restoration to health of chlorotic trees has been very pronounced. In certain instances recovery has resulted after such extensive damage that little more than the trunk of the tree remained.

Trace elements other than iron in plant nutrition. In addition to iron, trace amounts of zinc, copper, manganese, boron, and molybdenum are essential to plant growth, and must be present in trace quantities in soils if the health of the plant is to be maintained. With the exception of boron and molybdenum, which are present in soils as anions, these metals form stable complexes with chelating agents such as the aminopolycarboxcyclic acids. It is therefore possible to control the levels of zinc, copper, and manganese in the soils and in nutrient solutions by supplying the proper amount of metal chelate and chelating agents in a specified pH range. The use of the zinc chelate of EDTA in maintaining healthy growth of plants has been reported, and it has also been found that under conditions of excess arsenic in the soil the addition of zinc and iron(III) chelates have improved plant growth. In many areas, such as the fruit-growing sections of Florida and California, it is customary to apply a yearly leaf spray containing a zinc salt (2). Experimental work is being carried out in the use of various zinc chelates in foliage sprays. Excellent growth response has been observed with roses in the soil application of manganese EDTA, and the application of chelated manganese has been shown to produce an increase both in the yield and the sugar contents of grapes.

Metal chelates in animal nutrition. Metal chelates have also been used in a variety of ways in animal nutrition. Perhaps the most satisfactory way to introduce trace metals into the body is to employ food which contains ample amounts of these metals. Therefore, when plant products are deficient in a metal, such as iron, the resulting deficiency causes adverse effects in the animals which consume these products. Therefore indirectly, the use of metal chelates in plant nutrition may also well insure that animals fed on the products which are harvested from these plants will obtain sufficient amount of the metals required. There is, however, the possibility of the direct introduction of the metal chelate compounds into feeds and drinking water. Little experimental work has been done on direct animal nutrition with metal chelate compounds, but there is some evidence to indicate that the addition of metal chelates to feed increases the efficiency of oral ingestion of the metal compared to that which is obtained by the use of inorganic metal salts.

The anemic condition resulting from lack of iron is one of the most common trace metal deficiencies encountered in general medical practice. Houlihan and coworkers (10) have developed an effective iron chelate for oral administration of iron which has superior properties to other materials commonly employed. It has been reported that the copper(II)-EDTA chelate is four times as effective as inorganic copper salts in copper nutrition of dogs when the copper chelate is added directly to the feed.

One of the more important applications of metal chelates in animal nutrition is in the use of various chelating agents in food preservation. Traces of metals in various foods may be introduced by the processing machinery used, or by containers used in the storage of food. For example nickel is frequently introduced in the production of fats from the catalysts used in the hydrogenation of vegetable oil. Traces of such metals as copper, nickel and iron have catalytic activity toward chemical oxidation reactions which frequently result in the destruction of important food constituents. For example, traces of copper may cause the destruction of Vitamin C; traces of copper, nickel and iron promote oxidative destruction, i.e., oxidative rancidity of vegetable oils, fats, and soap. It is now a common practice to add chelating agents to food products when such metal contamination may cause serious trouble. For example, certain soft drinks, which contain appreciable quantities of ascorbic acid, frequently contain small amounts of EDTA to chelate catalytic traces of metals which may be derived from metal containers in which the materials may have been stored. Metal chelates are also used in jams and jellies primarily for the purpose of clarification, since many of the turbidity-producing solids are merely due to calcium, magnesium, or other polyvalent metal compounds which are dissolved by EDTA. As mentioned above, one of the most common uses of chelating agent in food products is the addition of traces to soaps, fats, and oils to counteract this effect of catalytic amounts of metal residues.

In many of the applications of chelating agents in food processing, the chelating agent is not retained in appreciable amounts in the final product. For example, EDTA has been found very effective in the removal of poisonous spray residues from fruits, particularly when lead compounds are used. The removal is simply accomplished by the addition of chelating agents to the washing medium. Both the EDTA and the metal chelates are soluble in water, and consequently are removed by rinsing.

Treatment of heavy metal poisoning. Chelating agents, such as EDTA, are frequently used to suppress the ionic form of metals which are effective poisons. In many cases, too, such reagents aid in the excretion of chelated metals through retention of solubility. For example, aluminon, the ammonium salt of aurintricarboxylic acid, has been used as an antidote for acute beryllium poisoning. It is of interest to note that fresh fruits were once used as a treatment for nickel "itch." The citric acid present in the fresh fruits served as the chelating agent to complex the nickel. 2,3-Dimercaptopropanol (BAL) has also been used to form chelates with toxic metals. It is said to be superior to EDTA for mercury poisoning. EDTA, however, is widely used, notably for lead. It is administered in the form of the disodium calcium EDTA.

Surplus iron is absorbed by the body, but this may be partially removed by treatment with calcium EDTA. Due to the relatively stronger bond formed with iron, the calcium is replaced by iron and the iron excreted as the chelate. An analogous condition occurs with copper. A copper storage disease, known as Wilson's disease, results from excessive storage of copper in the tissue. This has been treated with EDTA and BAL.

Chelates have also been used in medical diagnosis by x-ray studies. It is necessary for this purpose to introduce certain heavy metals into the body which will impede the passage of x-rays. Unfortunately most of these metals are toxic, and cannot be taken in soluble inorganic forms. Chelates with strong chelating agents, such as those with EDTA, are relatively non-toxic, and can be used for this purpose. Thus lead-EDTA chelate can be used for x-ray contrast purposes (17).

Disodium calcium EDTA has been used for radioactive decontamination, and to accelerate excretion of radioactive products. The use of

EDTA in the treatment of plutonium poisoning has been described by Foreman and coworkers (6, 4, 5, 7) and by Hamilton and Scott (8). Plutonium destroys bone marrow and causes osteitis and osteosarcoma. Studies have indicated that elimination of plutonium is rapid and effective when EDTA is administered immediately after exposure. Yttrium is also readily eliminated as the EDTA complex (3).

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ANTHROPOLOGY

Chairman: KING B. HUNTER, Indiana University

EMILY J. BLASINGHAM, Loyola University, was elected chairman for 1966

Morphology of the Nasal Bones of the American Negro

SUDHA S. SAKSENA, Indiana University

The purpose of this paper is to provide a morphological and metrical description and an expression of the variability in the nasal bones of a sample of adult male American Negro crania.

The data for this study is provided by a series of craniograph diagrams of eighty-one American Negro crania, which on the basis of an aggregate of morphological characteristics constitutes a relatively unhybridized series (1), from the T. Wingate Todd collection at Western Reserve University, which were drawn by Dr. Georg K. Neumann of Indiana University.* The original series of eighty-one individuals was reduced to sixty-five due to the exclusion of the specimens with damaged nasal bones.

A. METRICAL OBSERVATIONS

A number of measurements and indices were taken to express the variability in form of the nasal bones and to facilitate the quantification of the data.

The dimensions of the nasal bones

The following measurements have been taken on the nasal bones:

1. Length of the nasal bones—The distance from the naso-frontal suture to the free extremity of the nasal bones in the mid-sagittal plane (nasion to rhinion).
2. Upper nasal breadth—The distance between the maxillo-naso-frontal points on the right and the left sides in a horizontal plane.
3. Minimum nasal breadth—The minimum breadth of the two nasal bones, measured between the two lateral margins in a horizontal plane, wherever it occurs.
4. Maximum nasal breadth—The maximum breadth, of the two nasal bones, measured wherever it occurs between the two lateral margins in a horizontal plane.
5. Lower nasal breadth—The distance between the points at which the naso-maxillary sutures terminate at the nasal aperture on both sides.

An examination of Table 1 demonstrates that the most variable measurement is length, and least variable that of the maximum breadth of the nasal bones. The highest standard deviation $\partial = 3.39$ occurs again in the length of the nasal bones, and the lowest values in their minimum and the maximum breadths.

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* The writer wishes to express her appreciation to Dr. Neumann for guidance and provision of data for the preparation of this paper.

TABLE 1

Measurements and Statistical Constants of the Nasal Bones

Measurements	Range (in mm.)	Mean (in mm.)	Standard deviation (in mm.)	Coefficient of variation (in mm.)
1. Length of the nasal bone	13.4-30.0	19.9	±3.39	19.4
2. Upper breadth of nasals	7.3-17.5	13.5	±0.84	6.2
3. Minimum breadth of nasals	6.0-13.4	9.5	±0.60	6.3
4. Maximum breadth of nasals	12.8-21.4	18.9	±0.68	3.5
5. Lower breadth of nasals	8.5-21.6	17.4	±0.73	4.1

Nasal module

A module has been calculated for each set of nasal bones, serving as a criterion of size.

The module has been calculated in the following manner: Nasal module =

$$\frac{\text{Length}(1) + \text{Minimum breadth}(3) + \text{Maximum breadth}(4) \text{ of the nasal bones}}{3}$$

The nasal bone module ranges from 12.4 to 20.1. The mean is 16.8. The standard deviation reveals a variability of ±1.85.

Indices

Transverse index of the nasal bones:

$$\text{(a)}\quad \frac{\text{Minimum breadth of nasals}(3) \times 100}{\text{Upper breadth of nasals}(2)}$$

$$\text{(b)}\quad \frac{\text{Minimum breadth of nasals}(3) \times 100}{\text{Maximum breadth of nasals}(4)}$$

The two transverse indices indicate the relative proportions for the width of the nasal bones. They denote the relative degree of the direct extension of the naso-frontal and naso-maxillary sutures as well as the relative degree of constriction of the nasal bones. The range for index (a) is from 50.0 to 129.41, and that for index (b) from 28.25 to 81.58, yielding means of 78.32 for the former and 50.12 for the latter. The standard deviations exhibit high values, indicating a variability of ±12.64 for index (a), and ±10.63 for index (b).

B. MORPHOLOGICAL OBSERVATIONS

1. Course of the naso-frontal suture.

Three main categories are distinguished both on the basis of the course of the naso-frontal suture and the naso-maxillary suture. These forms are represented in Fig. 1, with some of their variants. The dome form continues directly into the fronto-maxillary suture on either side, whereas the remaining seven—gable, arch, club, trapezoidal, pit, box and pin-head forms—are set off angularly from the naso-maxillary-frontal point. Tabulating only the forms found in our sample, the gabled course of the suture is represented in seven cases, i.e., 10.76%; the rounded course (i.e., domed, arched, club and trapezoidal with 32.30%, 13.84%, 7.69% and 6.50% respectively) represented in thirty-eight cases, i.e., 58.46%; the square form (i.e., pit, box, and pin-head with 1.53%, 21.53% and 7.69% respectively) occurring in twenty cases i.e., 30.78%.

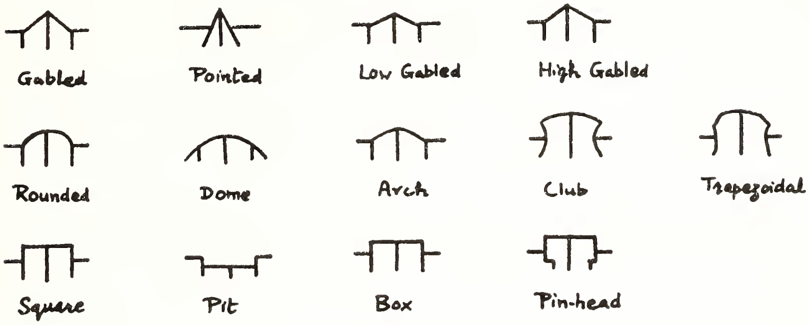

Figure 1. Course of the naso-frontal suture and its variants.

2. Constriction of the nasal bones.

A scale for the constriction of the nasal bones is given in Fig. 2.

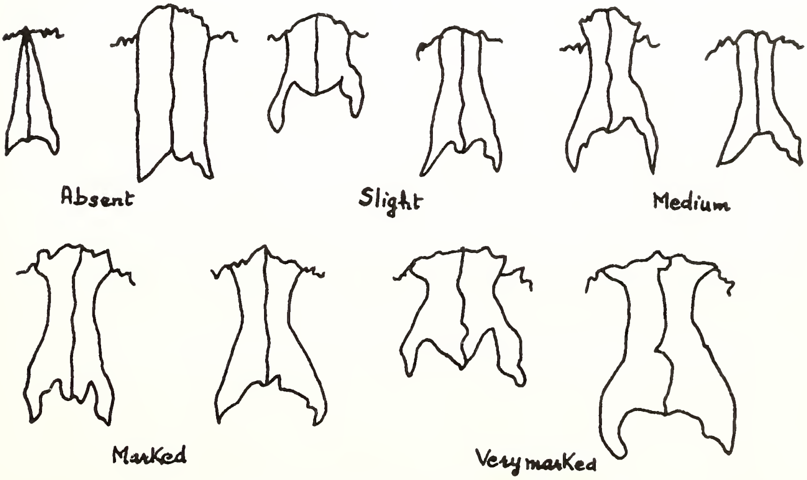

Figure 2. Constriction of the nasal bones.

The constriction is absent in only one case, i.e., 1.53%; slight in thirty-four cases, i.e., 53.86%; medium, marked, and very marked, in 27.68%, 15.38%, and 1.53% of the cases, respectively.

3. **Course of the lower margin of the nasal bones.**

Three categories showing the variability of the lower margin of the nasal bones are illustrated in Fig. 3.

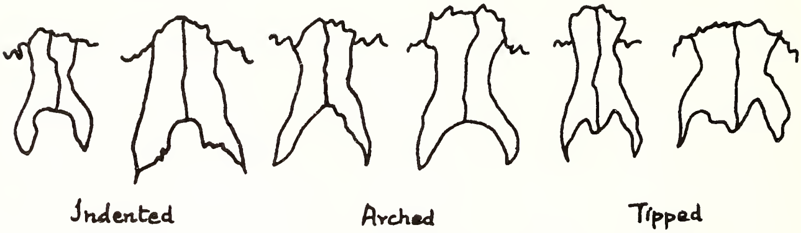

Figure 3. Course of the lower margin of the nasal bones.

The indented edge is represented by fifty-one cases, i.e., 76.93%; the intermediate arched or neutral edge by six cases, i.e., 9.23%; and the tipped edge by eight cases, i.e., 13.84%.

C. SUMMARY AND CONCLUSIONS

On the basis of a statistical analysis of the six measurements and the module of the sample, the series appears to be low in variability, that is, rather homogeneous in nature. On the other hand the two transverse indices of nasal bones indicate considerable variability in form.

As regards the analysis of the morphological characteristics, the round course of the naso-frontal suture and the indended course of the lower margin of the nasal bone, both characteristics occur in a very high frequency. By the employment of these scales it is possible to illustrate the typical forms of the nasal bones of our sample, and note that the most variable feature appears to be the degree of constriction of the bones, which this series exhibits.

In summary, this brief consideration of the morphological variation in the form of the nasal bones of a selected sample of American Negroes, demonstrates that on the basis of its low variability it can be considered racially homogeneous, and probably representative of the West African population from which it is derived.

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Methodological Limitations In The Location Of Underground Objects By Electrical Resistivity

ROBERT M. LITTLE, Indiana University

Electrical resistivity as applied to the field of archaeology is only one approach in the ever-growing family of scientific devices that enable the archaeologist to increase his efficiency in organizing and developing work programs in field projects. The days of the classical site, with hundreds of laborers removing tons of rubble, guided by a handful of experts, are just about over. Increased labor costs in North America and Europe, as well as rising nationalism in other areas of the world, have intensified the need to locate quickly and accurately the objectives of field projects.

Resistivity surveying has been a tool in geological survey projects for over forty years, but it was first applied to archaeology in 1946 (1). Considerable improvements in design and portability have been made in the intervening years and today it is a standard piece of equipment on many projects around the world.

Resistivity surveying essentially is an observation of the conductivity of the ground in specific areas at varying depths. The average resistance pattern will vary widely depending on the type of soil and its moisture content (6). The equipment needs to be versatile enough to handle these variations while at the same time be sensitive enough to detect the presence of an anomaly in any given range. Since there is a direct relationship between soil conductivity and moisture content, an object is indicated when it either retains more moisture than the surrounding area and gives a reading of less resistance, or it excludes moisture, such as a void, or hard solid object, and thereby indicates more resistance. The method has the advantage of being relatively economical and simple to operate, and is not limited or affected by metallic objects or magnetic anomalies.

However, all presently available systems have limitations, and because of this, several types of equipment are frequently used on the same set of problems. The electrical resistivity approach has two such handicaps. Some moisture must be present. This is not a serious limitation for most of South America, Europe, and many parts of Asia and Africa. It works well in eastern North America, and should be usable in most of the plains area and the Northwest. It becomes very limited, however, in areas such as Egypt, Arabia, and in North America's Southwest. Professor Hanfmann of Harvard reported that an M.I.T. team did not obtain satisfactory results at Sardis in Turkey two years ago, but the Lerici Foundation in Rome has received world-wide attention for work done at Tarquinia in Italy on Etruscan tombs (7). No doubt, all remember how Engineer C. M. Lerici developed the technique of using a power-driven auger to drill down into a tomb, insert a periscope with a light attached to the base, and with mirrors, photograph and even televise the contents of the tomb without excavating it. The tombs themselves, however, were located by using electrical resistivity equipment (4). The other limitation of resistivity surveying is the labor involved. Four probes must be inserted into the ground and the depth of the probe penetration must be controlled. The probes must be placed in a nearly straight line at specific intervals, with cables attached to all four probes from the main piece of equipment. In spite of this, the use of a fifth probe, a change-over-switch, transistorized circuit, and skilled operators, up to 300 readings per hour have been made, but this cannot be kept up for extended periods of time (1). This speed approaches that available with a magnetometer, but it is more demanding and tedious.

Let us now examine the recommended set-up for a reading. Since there are, to some degree, natural earth currents measured as direct current, we use an alternating current to eliminate their potential interference. When only two probes are used, the voltage measured between the probes will not only measure the resistance in the ground

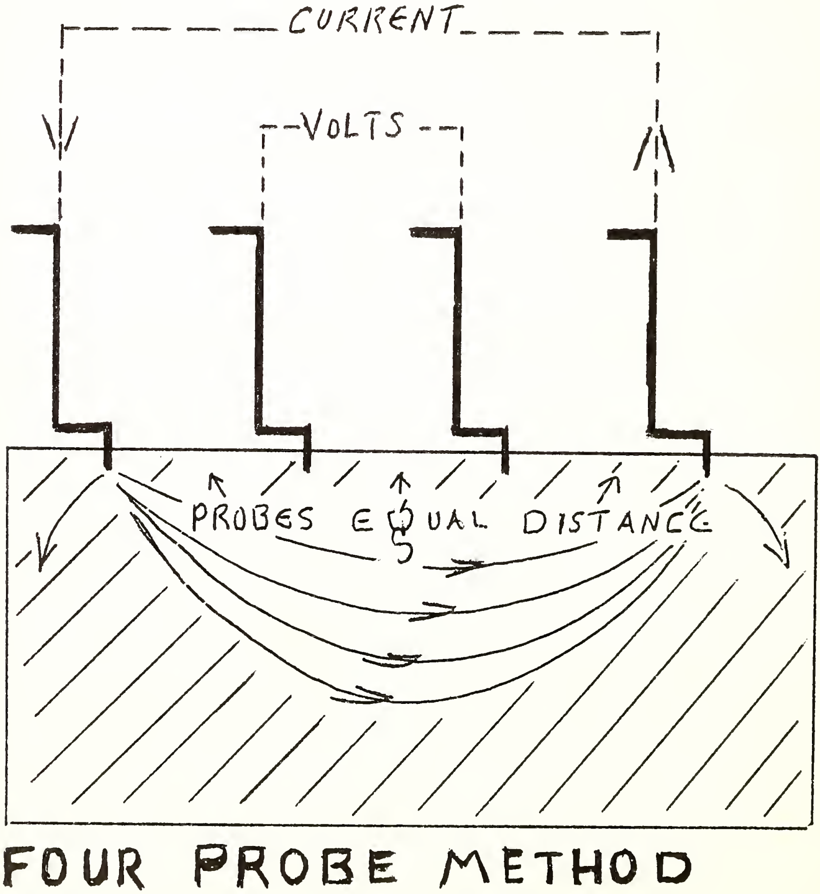

Figure 1. Four probe method.

but will measure the resistance between probe and ground. A loose probe or surface wetness would give false indications. Therefore, the four-probe method is recommended (Fig. 1). An alternating current is sent through the outer probes and, completely independent of these probes, two inner probes measure a voltage that is a very small fraction of the total voltage, but is directly proportional to the current flowing. Thus we have the relation:

> Effective resistance (R) equals the voltage across the inner probes divided by the current through the outer probes.

Now when we have the probes equally spaced, the specific resistivity (r), which is what we are after, is related to the effective resistance (R) as follows:

$$r = 2 \pi d R$$

and where (d) is in feet and (R) in ohms, we then have

$$r = 191 \times d \times R \text{ ohm-cm}$$

and it is in these terms that the findings are reported (1).

In order to better acquaint ourselves with electrical resistivity, we decided to build a very simple and inexpensive piece of equipment and to test the basic theory and procedures. Taking a 12-volt auto battery, we drew the direct current through a Radiart Vipower 12-volt, 100-watt inverter, converting it to 60-cycle alternating current, and then on through a 7½-amp, 0-140-volt Powerstat for controlling the current. We applied 100 milliamps of alternating current through the outer probes at 80 volts, but varied the voltage throughout the readings to keep the milliamps constant. We then took our readings off the inner probe voltmeter and calculated the specific resistivity (r).

Professional equipment includes a Null balancing circuit. A calibrated rheostat on the outer probe side is balanced with the voltage developed between the inner probes, and when an anomaly comes into the path of the inner probes, the Null detector is thrown off balance and the variation is recorded. This eliminates calculations.

All four probes should be equally distributed from each other. Their distance is determined by the depth of penetration of the current that the operator wishes. The penetration is 1.5 times the distance between the probes. The penetration of the probe itself into the ground is important. An ideal condition is 1/20th the distance between probes. However, this becomes impracticable when working in one-foot probe separations. As a rule, 3″ probe penetration is necessary. At one-foot probe separations, the error will be approximately 10%. However, with two-foot separations, the error is reduced to approximately 2%. Fortunately, most material will be found below a two-foot depth and the percent error is greatly reduced.

To demonstrate this particular system, a laboratory project was set up. A flat area in Marion County was selected that had not been cultivated for at least ten years. A pit was dug 24″ square and 36″ deep. An empty wooden box (approximately 1000 cu. in.) was placed in the center at the bottom. The first set of readings were set for a four-and-one-half-foot current penetration with no indications of variations. The second set was taken, still over the "known object," for three-foot penetrations with very little variation. The third set was read at the two-and-one-half-foot level and gave an excellent indication in the correct area, which gave nearly a 1000 ohm-cm indicated variation. The fourth set at the one-and-one-half-foot depth exhibited a more erratic pattern, but not as strong or consistent as the actual area of the object. As has been pointed out, at one-foot probe separations, the margins of error are higher due to probe penetrations, and therefore more erratic readings would be expected (Fig. 2). Parallel readings at constant depth with the first set going through the object and the second set missing the object also showed a nice contrast (Fig. 3). The solid lines were reread one week after the first readings with exactly the same results. The dotted lines indicate readings that were taken over the same area one month later on a day following a light rain. The resistance was lower, but there was reasonably good reproduceability of pattern.

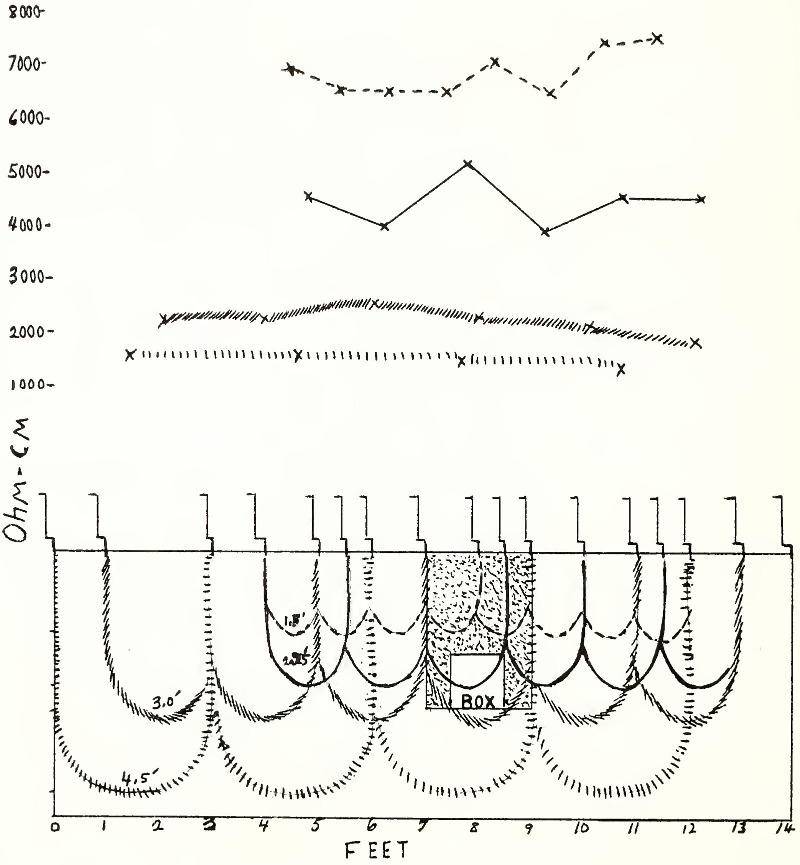

Figure 2. Locating known object.

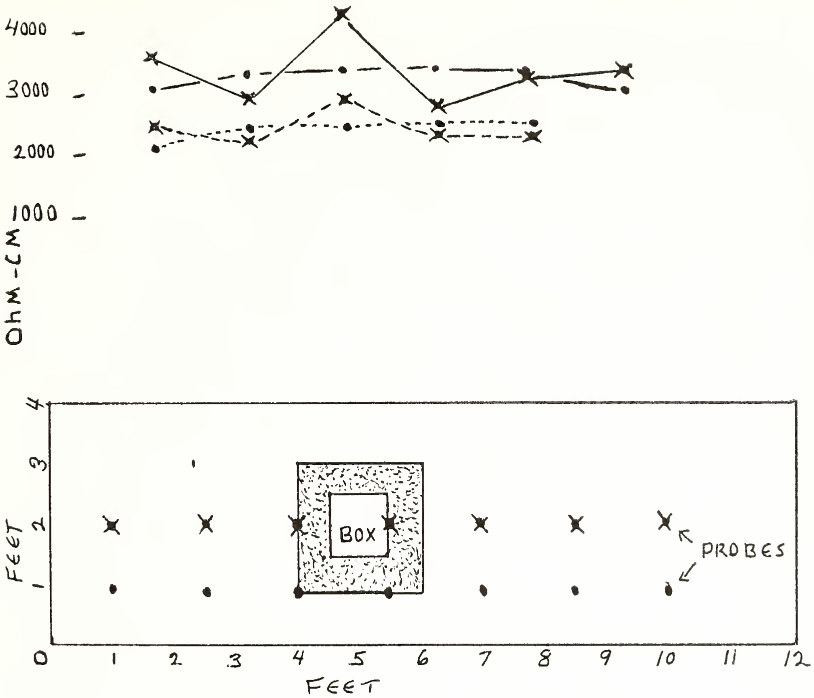

Figure 3. Parallel profile of known object.

There has been little opportunity to field test this equipment. Before the Bowen Site, a late woodland village located at Keystone Avenue and White River just north of Indianapolis, was closed by J. C. Householder last year, some very preliminary resistivity surveying was tried. At that time, the area available was considerably worked over and disturbed by multiple occupation. The object was to find indications of refuse or storage pits. The results were encouraging, but too limited in scope and perhaps too subjective in interpretation to be conclusive. The results did indicate good possibilities with professional equipment on this type of material.

The results obtained in the laboratory project also indicated good future possibilities for testing in this area. On salvage operations where time is short because of highway or building construction, a resistivity survey might be very desirable. On observing a number of burials uncovered and removed at the Bowen Site, it was noted that many of the skulls contained no worked soil and were thus very fragile and subject to damage. It is hoped that with refinements such voids could be detected, and the skulls could be uncovered with much less risk of damage.

Of course, professional equipment is available and should be used on regularly projected sites. The "Geohm," manufactured in Germany, is very dependable and relatively inexpensive. It has been tested extensively in this country by the Applied Science Center of Archaeology, University of Pennsylvania (8). The Martin-Clark Instruments Company of Surry, England, make a more sophisticated instrument which contains the desirable change-over switch that speeds up field readings. It is being used by the Historical Society of Williamsburg, Virginia, among others. The Lerici Foundation in Rome has built a far more complicated instrument, but Elizabeth K. Ralph, Associate Director of ASCA, University of Pennsylvania, reports the "Geohm" as being just as dependable.

As mentioned previously, the resistivity survey method is frequently used with other equipment such as the proton magnetometer (5). The late Dr. Glenn Black was a prime force in inaugurating the use of a proton magnetometer at Angel Mounds near Evansville. Dr. Scollar from Germany has developed a special digital differential proton magnetometer. Elizabeth K. Ralph is now in Southern Italy continuing work in the search for the ancient Greek city of Sybaris, using a Varion Rubidium magnetometer which has many uses (11) and has been used there with excellent results (9). The University of Pennsylvania is also experimenting with a sonic device using a frequency of 600 cycles (2, 8). The author is currently working on equipment using electromagnetic waves in an effort to eliminate the need for probes and at the same time not be limited by metallic interferences. Similar methods are used in geological survey work, but depends on secondary magnetic effects from ore bodies (3).

A new approach currently being investigated is the possibility of locating anomalies by observing, with a sensitive iron core coil, the angle of deflection (resulting from the anomaly) of an alternating current driven into the ground between two widely spaced probes. The alternating current sets up a magnetic field which induces a voltage into the coil. The operator would set the coil in a Null position 2-3 inches above the ground and walk between the probes. The coil would be connected to a portable sub-miniature audio amplifier. As the alternating current is deflected, the Null balance is thrown off which is detected through the audio output of the amplifier (10).

A resistivity survey was made over an area that was known to contain a concrete form approximately 3′ x 5′ x 3′ deep and buried at a probable depth of 4 feet. Its presence was easily picked up on the resistivity profile (Fig. 4). Two probes were then placed at both ends of the survey run (approximately 30′) and 100 milliamps of alternating current was put through the ground at about 80 volts. An iron core coil was then placed in a Null position and the operator walked between the probes. A deflection was indicated by the audio output in the same area indicated by the resistivity profile. The same procedure was repeated over the first experimental area (Fig. 2), but the present coil did not pick up any deflection. A more sensitive coil is planned.

Much work remains to be done, and new doors of knowledge will be opened. Some archaeologists look upon these devices as gimics, while others place great value in them. M. J. Aitken, in his book, Physics and Archaeology, has put it all in its proper perspective. "These techniques reveal the location of certain types of abnormal disturbances

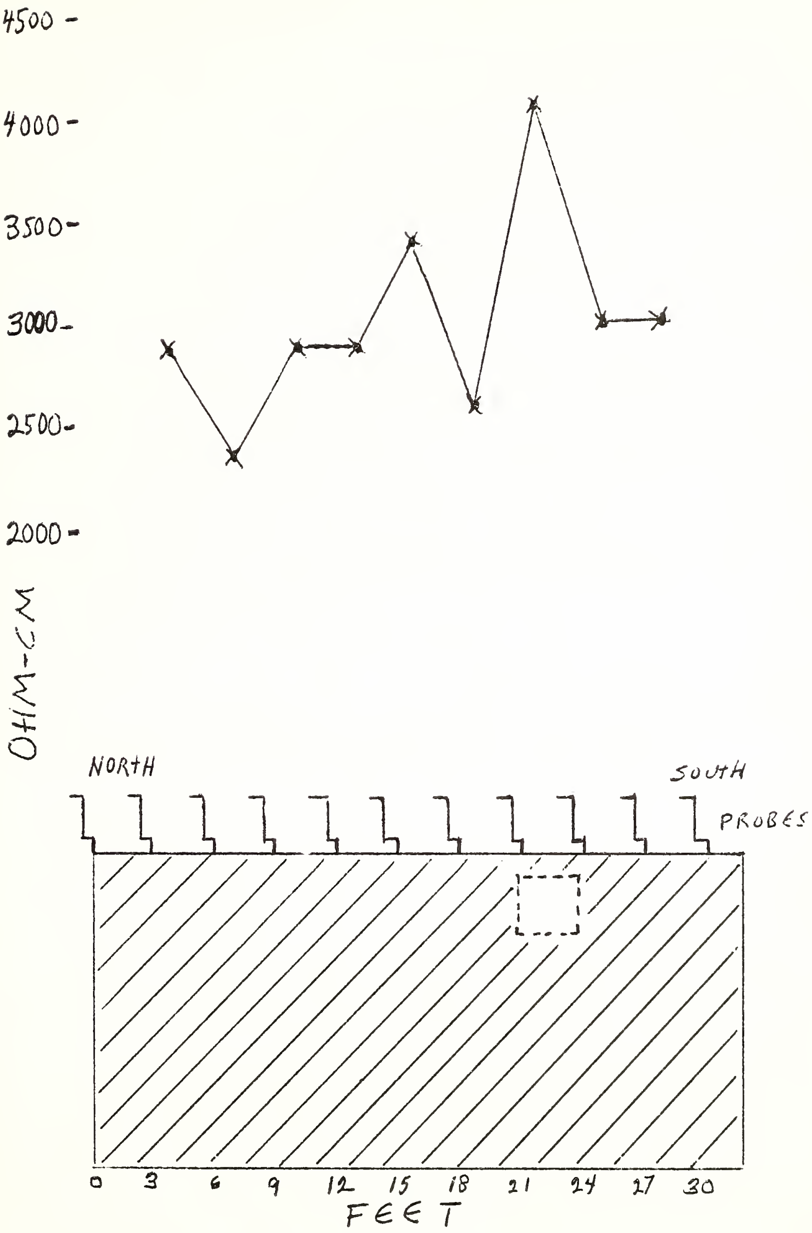

Figure 4. Profile of concrete object.

beneath the surface. They should not be over-estimated; they do not relieve the archeologist of the need to use his spade—but they do suggest the most fruitful spots in which to insert it" (1).

Summary

There is an ever-growing field of scientific devices that are available to the archaeologist today. One of these, Electrical Resistivity, using the four-probe method, is relatively inexpensive and simple to operate. It can be a good useful tool in making more efficient archaeological field work in Indiana as well as in other parts of the world. In measuring the moisture content or the lack of it in the ground, Electrical Resistivity is free from the problems of magnetic interference associated with magnetometers and mine detectors.

A variation of the above method using two very widely spaced probes, high voltage alternating current and an iron core coil with an audio amplifier to detect the angular deflection of the current when confronted with anomalies is also under investigation and shows some promise.

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BACTERIOLOGY

Chairman: MORRIS WAGNER, University of Notre Dame
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ABSTRACTS

Pathogenesis of mouse hepatitis virus in germfree and conventional mice. GEORGE LAVELLE and THEODORE J. STARR. University of Notre Dame, Lobund Laboratory.—Triolein-protected mice against an otherwise lethal challenge of cortisone and mouse hepatitis virus (MHV-1). In addition, triolein stimulated the reticuloendothelial system as measured by the clearance of colloidal carbon from the blood. The growth of MHV-1 in mouse livers was studied under conditions of triolein and cortisone pretreatment. Virus titers of conventional anmals were significantly higher than germfree animals when mice were challenged with virus alone. Cortisone increased titers in germfree mice but these remained lower than conventional mice. After triolein pretreatment, however, germfree titers were greatly elevated and comparable to that obtained with virus alone in conventional animals. It is suggested that the enhanced ability of germfree animals to support virus growth is associated with triolein stimulation of the reticuloendothelial system. The mechanism whereby triolein protects against lethal doses of cortisone and virus is currently under consideration. The problem considers interferon production and carbon clearance.

Inhibitory Effects of Human Indigenous Bacteria on ***Corynebacterium diphtheiae*** **and** ***Streptococcus pyogenes.*** PAUL C. LEAVIS, Forsyth Dental Center, Boston, Massachusetts.—Twenty-two strains of bacteria indigenous to the oral cavity of man were isolated from throat swabs in order to determine whether they could inhibit growth of the pathogens, *C. diphtheriae* and *S. pyrogenes.* This effect was tested *in vitro* by seeding petri plates containing Trypticase Soy Agar (with 0.25% glucose added) with the two pathogens and then spotting the plates with the human indigenous bacterial strains. Six strains of the 22 tested were found to inhibit growth of the *C. diphtheriae*, when grown under anaerobic conditions. However, none of the strains affected *S. pyogenes.* The inhibitory organisms included 2 *Staphylococcus* strains, 3 strains of *Streptococcus salivarius* and one of *Streptococcus mitis.* The most effective inhibitor among these was a *Streptococcus salivarius* strain which produced a distinct inhibitory zone of approximately 1.53 cm^2 in area. The other *S. salivarius* strains produced inhibitory zones of 0.94 cm^2 and 0.39 cm^2, the *S. mitis,* 1.05 cm,^{2} and the *Stpahylococcus* strains, 0.63 cm^2 and 0.57 cm^2 in area respectively.

The most effective inhibitor was then tested *in vivo* using gnotobiotic mice. Duplicate broth cultures of *C. diphtheriae* sealed in glass ampules were surface sterilized with peracetic acid and introduced into germ-free isolators containing the test animals. One ampule was used to inoculate the test animals, and the other was removed from the isolator and cultured in T. Soy Broth. The establishment of the pathogen was determined by culturing fecal samples on T. Soy Agar plates. When the pathogen became established in the animals, the same procedure described above was used to introduce the inhibitory organisms into the animals, and after 72 hours, fresh feces were again cultured. The results indicated that the inhibitor produced an approximate 50% decrease in the numbers of *C. diphtheriae* previously present as a monocontaminant in the animal.

Subsequent investigations are now being directed toward elucidation of the mechanisms involved in the inhibitory reaction.

Bacterial phagocytosis in the dorsal lymph sac of *Rana pipiens*. MELVIN E. EVERLY and ROBERT J. HANSON, Valparaiso University.—A literature search revealed little information on the process of bacterial phagocytosis in the common laboratory frog, *Rana pipiens*. Massart observed that a fine capillary tube containing *Staphylococcus pyogenes albus* placed in the large lymph sac of frogs induced a swarm of leukocytes to enter the tube within 12 hours. Nobel showed that an intravenous injection of bacteria caused an increase in monocytes in the blood of frogs. Further study of bacterial phagocytosis by frog leukocytes seemed warranted.

Killed *Staphylococcus epidermidis* were injected into the dorsal lymph sac of urethan anesthetized *Rana pipiens*. Drops of lymph were made of the fluid on slides, stained with Wright's stain, and examined for the types of cells in the fluid and for intracellular cocci.

The number of leukocytes varied appreciably from animal to animal. On the average there were 80 percent lymphocytes, 12 percent monocytes and large lymphocytes, and 8 percent granulocytes. After injection of the bacteria, there was a 2-fold increase in the number of monocytes in the lymph fluid, and this occurred as early as one hour after the injection. Phagocytosis, as evidenced by intracellular cocci, occurred as early as 15 minutes after bacterial injection. Intermediate lymphocytes, the stage prior to cell maturation into monocytes, were the most active in the uptake of the bacteria, although the number of intracellular cocci was not large and only 20 percent of the cells participated. Some phagocytosis of cocci also occurred with monocytes and with polymorphonuclear leukocytes.

In order to have some comparison for the phagocytic activity in lymph fluid, cocci were injected into the peritoneal cavity of frogs, fluid samples taken periodically for smears, and the same staining and examining procedures followed. Less phagocytic activity by intermediate lymphocytes was observed while more polymorphonuclear leukocytes had phagocytosed cocci. Through the 4 hours of the study there was no significant increase in the numbers of cells in the peritoneal fluid.

These studies show that phagocytosis of killed staphylococci occurs in the frog, *Rana pipiens*, primarily by intermediate lymphocytes in the lymph fluid and by polymorphonuclear leukocytes in the peritoneal cavity.

Tolerance to the Induction of Interferon by Vaccinia Virus in Germfree Mice[1]

Richard G. Considine and Theodore J. Starr,
University of Notre Dame

Introduction

Interferon is produced in response to the treatment of animal cells with certain viruses. It is a cell-produced protein which inhibits multiplication but does not directly inactivate animal viruses (5). This characteristic represents an initial defense mechanism of the host against viral invasion. It is probable that intrinsic host resistance is determined by local tissue factors and foremost among these is the interferon mechanism. Antibody responses to many acute viral infections are often too little and too late to influence the outcome of viral diseases (5). Rabbits were rendered tolerant to an otherwise effective interferon-inducing dose of virus by pretreatment with either sindbis virus or with *E. coli* endotoxin (3). In our studies, germfree mice were made tolerant to the induction of interferon by vaccinia virus. Germfree mice were used because of their lack of a bacterial flora which has been shown to influence interferon production (4). Vaccinia virus was selected because it is a poor inducer of interferon (2). This characteristic may exemplify an anti-interferon mechanism.

Materials and Methods

Cells. The L strain (clone MCN) of Earle's mouse fibroblast was carried in a nutrient medium (NM) containing 60% Scherer's and 30% 199 supplemented with 10% horse serum. The pH was adjusted to 7.2 with 5.0% sodium bicarbonate. Penicillin (100 units/ml) and streptomycin (0.1 mg/ml) were used.

Virus. Vaccinia virus WR strain (neurotropic) was maintained by passage in MCN cells. Dilutions of stock virus were adsorbed for 2 hr at 37°C on confluent sheets of 48 hr monolayers in screw-capped prescription bottles. Medium was added and bottles were reincubated for 24 hr. The vaccinia virus was harvested by the freeze-thaw technique. Fluid was clarified by centrifugation at 600 rpm for 10 min at 5°C. The clear viral suspension was vialed in 1 ml volumes and stored at —60°C. Vesicular stomatitis virus (VSV) used in the interferon assays was, also, propagated in MCN cells. The NM was, however, adjusted to pH 7.6. After a 45 min adsorption period, virus-infected cells were incubated at 37°C for 1 to 2 days. VSV was harvested as described for vaccinia virus.

Virus Titration. Vaccinia virus was assayed by the plaque method in MCN cells grown in falcon flasks (10^6 cells/flask). Stock virus was serially diluted in NM. One tenth ml of each dilution was introduced and thoroughly spread over the surface of the monolayer. After a 2 hr adsorption period at 37°C, the inoculum was decanted. The cell sheet was washed 2 times with 1 ml of NM. Two ml of NM was added to the flask. Following incubation for 48 hr, medium was removed and 2 ml of a dye solution (5% crystal violet in 20% ethanol) was added. The dye remained in contact with the monolayer for 2 to 4 min. Distilled water was used to wash excess dye from the cell monolayer. The plaques were readily visible and easily counted.

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[1] Supported in part by Grant NONR 1623-14 from the Office of Naval Research and the University of Notre Dame.

VSV was titrated by formation of plaques on MCN cells. Stock virus preparations were serially diluted in NM and adsorbed onto MCN cells for 2 hr as described for vaccinia. Flasks were incubated for 48 hr with a mixture of 2 ml double strength NM plus 2 ml of 2% Difco Noble agar. Within 48 hr, 0.5 ml of neutral red (1/2000) was added and plaques were counted after 2 hours.

Interferon Assay. Whole blood was collected and allowed to stand for ½ hr at room temperature. Serum was separated from the clot and centrifuged at 2,000 rpm. for 15 minutes. The serum interferon preparation was acidified to pH 2, and dialysed overnight against KCl-HCl buffer. To insure removal of infectious particles, the serum was centrifuged at 40,000 rpm for 2 hr. The preparation was assayed by the 50% inhibition endpoint of plaque formation on MCN cells, utilizing VSV as the challenge virus. One ml of diluted interferon preparation was adsorbed on MCN cells for 5 hours at 37°C. The VSV was introduced and the assay was performed as described in the above section.

Results

TABLE 1
Inhibition of Interferon Induction with High Titers of Vaccinia Virus.

Vaccinia Inoculum[1] (PFU)	Interferon Titer (Reciprocal of Serum Dilution)[2] Group 1	Group 2
1.9×10^9	11	—
1.9×10^8	15	15
1.9×10^7	48	40
1.9×10^6	36	35
1.9×10^5	<10	<10
1.9×10^4	<10	<10
None	<10	<10

1. Animals sacrificed 7 hours post-inoculation.
2. Interferon titers represent the 50% plaque inhibition endpoint of vesicular stomatitis virus on MCN cells.

Table 1 shows the relationship between virus challenge dose and interferon production seven hours post-challenge. Results of two series of experiments are shown. Germfree mice were challenged intravenously with 1.9 X 10^4 to 1.9 X 10^9 plaque forming units (PFU) of vaccinia virus. Maximum interferon induction occurred with a viral inoculation of 1.9 X 10^7 PFU. Challenges with either higher or lower viral concentrations yielded less interferon than this optimal dose.

Tolerance of mice to the induction of interferon by vaccinia after a prior challenge of vaccinia virus is demonstrated in Table 2. Mice were first inoculated intraperitoneally with vaccinia virus. The range of viral dosage was from 7.6 X 10^5 to 7.6 X 10^8 PFU. After 12 hours, all mice were again challenged with the optimum interferon producing dose (1.52 X 10^7 PFU). Seven hours after the second challenge, animals were sacrificed and serum samples collected. Mice which were prechallenged with vaccinia virus in excess of 7.6 X 10^5 PFU were rendered hyporeactive to an otherwise effective interferon-inducing dose of vaccinia. Both the time of induction, 7 hours, and the inducing dose of vaccinia virus, 10^7 PFU, were optimal for our system.

TABLE 2
Tolerance to the Induction of Interferon by Prechallenge with Vaccinia Virus

First Inoculation Vaccinia Virus[1] (PFU)	Second Inoculation Vaccinia Virus[2] (PFU)	Interferon Titer (Reciprocal of Serum Dilution)[3]
7.6 X 10^8	1.52 X 10^7	<10
7.6 X 10^7	1.52 X 10^7	15
7.6 X 10^6	1.52 X 10^7	15
7.6 X 10^5	1.52 X 10^7	38
None	1.52 X 10^7	38
None	None	<10

1. Twelve-hour interval between inoculations.
2. Animals were sacrificed 7 hours after the second inoculation.
3. Interferon titers represent 50% plaque inhibition endpoint of vesicular stomatitis virus on MCN cells.

Discussion and Summary

Even under optimal conditions, vaccinia virus does not induce animals to produce high concentrations of interferon. In studying this phenomena, we observed that increasing dosages of vaccinia, above the optimal dose of 10^7 PFU, induced germfree mice to produce less interferon. It is possible that the higher doses of vaccinia are toxic to the interferon producing cells in the reticuloendothelial system. Thus, a hyporeactive or tolerant state was created. This phenomenon of hyporeactivity to vaccinia virus is augmented (Table 2) by a vaccinia virus challenge 12 hours prior to an otherwise effective interferon-inducing dose of vaccinia.

We hope that further investigations, using this assay system, will disclose the nature of this vaccinia tolerance. This problem is being considered from the point of view that the vaccinia virus is toxic to the cells of the reticuloendothelial system of the mice. Vaccinia toxicity to mouse leucocytes has been demonstrated by Glasgow and Habel (1, 2).

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BOTANY

Chairman: John F. Schafer, Purdue University
C. Franklin Bishop, Goshen College, was elected chairman for 1966

ABSTRACTS

Nuclear changes and mitotic anomalies in tissue-cultured cells treated with extracts from marine algae. Theodore J. Starr, Mashiro Kajima and M. Diaz-Piferrer. University of Notre Dame, Department of Biology, Lobund Laboratory, Notre Dame, Indiana, and Instituto de Biologia Marina, Departmento de Biologia, C.A.A.M., Universidad de Puerto Rico, Mayaguez, Puerto Rico.—In a previous report, the antibacterial and antiviral activities of algal extracts were described (Starr *et al.*, Tex. Rep. Biol. Med., 20:271, 1962). Results of continued efforts to characterize and concentrate the active factor directed our attention to specific nuclear changes and mitotic anomalies associated with treatment of tissue-cultured cells of animal origin. Algal extracts were added to cells on cover slips in Leighton tubes. Preparations were fixed, stained with acridine orange, and examined by fluorescence microscopy. Observed effects on normal development were multiple: 1) amitotis was widespread, large numbers of irregularly shaped nuclei were evident, multi-nuclear cells were apparently formed by budding and fragmentation of the nucleus; 2) after a short exposure to active algal fractions, metaphase configurations increased from a normal of 2 to 4 percent to more than 20 percent, 3) apparently some micronucleated cells were formed in a manner similar to that obtained with colchicine (Starr *et al.*, Tex. Rep. Biol. Med., 21:412, 1963); and 4) in some instances miniature cells in clusters were observed and such anomalies may have resulted from a multiple cytokinesis.

Tissue Observations and Comparisons in the *Knotted Leaf* (Kn) Mutant of *Zea Mays* L. Harvey D. Telinde and S. N. Postlethwait, Purdue University.—The leaf of *Zea Mays L.* is characterized by having a flat blade delimited from the sheath by a so-called intercalary meristem.

The *Knotted (Kn)* gene conditions the production of localized protuberances or "knots" of tissue in the leaf blade. The nature and distribution of these protuberances suggest a relationship to a displacement of intercalary meristem tissue into the blade. These localized areas of meristematic activity surrounded by non-dividing differentiating cells result in folds or invaginations of leaf tissue.

Young leaf tissue, intercalary meristem tissue, knotted leaf tissue, and normal mature leaf tissue were histologically compared revealing certain similarities and differences between the four tissue types. The distal end of a "knotted area" retains normal leaf characteristics. The immediate proximal end of a "knotted area" develops a ligule-like structure delimiting an immature area resembling young leaf tissue undergoing intercalary growth and a simulated leaf sheath.

These observations suggest that certain cells associated with lateral bundles may retain intercalary meristem characteristics and thus form islands of meristematic activity surrounded by maturing tissue. The resulting structure is interpreted as a displaced intercalary meristem.

Some Effects of Dimethyl Sulfoxide upon Seed Germination, Plant Growth, and Herbicide Activity. H. W. Mussell, B. Bucko, D. James Morré and R. J. Green, Purdue University.—Dimethyl sulfoxide (DMSO) may have applications in the plant sciences as a solvent for defoliants and herbicides. The effects of DMSO upon seed germination and plant growth were investigated using seeds of ten species soaked in various concentrations of DMSO. Results indicated no effect upon germination with concentrations up to and including 2.5 M DMSO. Concentrations of 5 M and 10 M DMSO delayed germination and in some cases caused a reduction in germination rate. DMSO concentrations that did not affect germination did not affect early growth. Daily foliar sprays of DMSO solutions did not affect the growth of cotton plants over a five week period. The only visible effect of the treatments was a slight leaf tip burn at the higher concentrations.

A preliminary field study using DMSO and Atrazine indicated that Atrazine is highly soluble in DMSO and the mixture can be applied to corn without affecting growth. Comparison of treatments indicated that the DMSO enhanced the effect of the Atrazine on dicrots but not on monocots.

Effects of DMSO upon 2,4-D penetration and activity will be discussed and attempts to define the mode of DMSO enhancement of 2,4-D action will be presented.

Work supported in part by a contract with the U.S. Army Biological Laboratories.

The metabolism of Arbutin by *Alternaria mali* and *Helminthorsporium carbonum*. Phyllis Conrad, Purdue University.—This study was conducted to compare the breakdown of Arbutin (the most commonly occurring glycoside in pear) by *Helminthosporium carbonum* and *Alternaria mali*. *A. mali* is weakly pathogenic, while *H. carbonum* is not pathogenic to pear. Unseeded and seeded broth extracts containing 10^{-2}M/1 arbutin were incubated at 28°C for one week and were then analyzed for arbutin, hydroquinone and quinone. After the solutions were centrifuged and filtered they were spotted on chromatograms. These were developed in 4:1:5 butanol, acetic acid, water and sprayed with diazotized sulfanilic acid. Results indicate that the two organisms do not metabolize arbutin in the same manner. *A. mali* apparently breaks arbutin down to hydroquinone and glucose. *H. carbonum* does not stop with hydroquinone. Solutions of arbutin with the organism showed no arbutin nor hydroquinone after one week's incubation. However, when sodium metabisulfite was added to filtrates of these and more arbutin was added, hydroquinone was detected after 4 days. Thus, it seems that *H. carbonum* breaks down arbutin to hydroquinone and then further breaks down hydroquinone to an unidentified compound or compounds.

Mature Plant Resistance of Oats to Crown Rust. BRIAN C. CLIFFORD and JOHN F. SCHAFER, Purdue University.—The development of mature plant resistance of *Avena sativa* L. to *Puccinia coronata.* Cda. var *avenae* Fras. & Led. was studied under growth chamber, greenhouse and field conditions. Resistance related to the age of the leaf at time of infection, older leaves being generally more resistant. The host: parasite interaction was influenced by temperature, resistance developing earlier at low temperatures in a range of 15-30°C. Neither infection type nor rate of symptom development was significantly affected by preinoculation temperature. Post-inoculation temperature was important in this respect. Comparisons between growth chamber, greenhouse and field experiments indicated the importance of low night temperatures in conditioning resistance. Day length in a range of 12-20 hours had no appreciable effect on the outcome of the host: parasite encounter. Resistance to the two rust races tested (264 & 294) was race specific and apparently governed by fairly complex genetic mechanisms. The temperature and ontogenetic components of resistance suggest that the activity of a resistance gene is modified by inhibitory mechanisms. It appears that the resistance gene is in a state of suppression in young leaves. At lower temperatures the degree of inhibition decreases with leaf development. At higher temperatures a higher level of inhibition is maintained.

Tordon, A New Synthetic Growth Regulator. WILLIAM EISINGER and D. JAMES MORRÉ, Purdue University.—Tordon (4-amino-3,5,6-trichloropicolinic acid) is a new herbicide which is potentially useful for vegetation control along highway right-of-ways and in other non-crop areas. Several sources have indicated that Tordon has growth regulatory properties. A series of biological tests was set up to investigate this possibility. In straight growth tests using etiolated oat coleoptiles, etiolated pea epicotyls and soybean hypocotyls, and green pea epicotyls, Tordon was shown to promote growth at low concentrations and inhibit growth at high concentrations. Translocation studies using leaf application of Tordon and 2,4-D on whole bean plants indicate that the two herbicides seem to translocate at approximately the same rate. In cell wall deformibility tests, only weight application experiments have been completed. Tests using the Instron (a mechanical stress analyzer) are planned. Tordon has shown considerable activity in the corn root inhibition tests. Inhibition kinetics have been compared to relate the modes of action of 2,4-D and Tordon. Studies using tissue culture have indicated differences in the type of callus induced by the two materials.

The mode of action of Tordon will be discussed in comparison with that of IAA, 2,4-D and other growth regulations.

Work supported in part by a contract with the U. S. Army Biological Laboratories and funds from the Purdue Joint Highway Research Project C-36-48C.

Determination of Auxin-induced Cell Wall Deformability in the Presence and Absence of Actinomycin D. COARTNEY, JAMES S. and D. J. MORRÉ, Purdue University.—The Instron (a mechanical stress-strain analyzer) was used to mechanically assess the changes in cell wall deformability accompanying auxin (IAA or 2,4-D) induced growth. Sections 1.0 cm in length were taken from 27-32 mm *Avena* coleoptiles, the 3d internode of light-grown peas or from dark-grown maize mesocotyls. These sections were pretreated in the presence or absence of actinomycin D (an inhibitor of DNA-dependent RNA synthesis) and then transferred to auxin to evaluate the effect of the actinomycin D pre-treatment. Growth measurements were made throughout the incubation period using a binocular scope fitted with a scale calibrated to the nearest 0.1 mm. Sections were then boiled in methanol for 4-5 minutes and stored in methanol until mechanical analyses were performed.

The results with light-grown peas and maize mesocotyls revealed that actinomycin D pretreatment severely inhibited auxin-induced growth and cell wall deformability. With *Avena* a small increment of auxin-induced growth and deformability remained even after a 6 hour actinomycin D pre-treatment. RNA determinations performed on similarily treated *Avena* sections suggested that RNA synthesis was only partially inhibited by such a pretreatment.

These results will be discussed in terms of the requirement for RNA synthesis for auxin-induced growth and cell wall deformability.

Work supported in part by a contract with the U. S. Army Biological Laboratories.

Characterization *Zea Mays* Root Cap Slime Secretion. D. D. JONES, D. J. MORRÉ, Purdue University and H. H. MOLLENHAUER, C. F. Kettering Research Laboratory, Yellow Springs, Ohio.—Dictyosomes of the plant Golgi apparatus are important organelles in concentration and modification of secreted substances. In the maize root tip, secretion is accompanied by hypertrophy of dictyosome cisterna to form large vesicles. These vesicle contents are released from the cytoplasm by fusion of the vesicle membrane with the plasma membrane (Mollenhauer, H. H., Whaley, W. G. and Leech, J. H., J. Ultrastructure Res. 5, 193-200, 1961). This system was selected for study of the physiology and biochemistry of the secretion process. During secretion, a slime droplet forms on the maize root tip, the size of which has been related by these studies to secretory activity. By utilizing an index rating of 0 to 10 mgs. of slime per root tip, steady state secretion kinetics (4 hrs.) were established with a Q_{10} of 1.57-2.3. The high Q_{10} suggests an active process. A temperature independent periodicity (period of 3 hrs.) was also indicated. Secretion amounts increased by supplying sucrose, lactose, and other carbohydrates. A 2-fold slime increase was obtained with 0.04 M sucrose. High sucrose concentrations inhibited slime secretion. Boric acid (20 mg/l) occasionally promoted secretion with variable results. No correlation was found between slime amount and growth rate.

A positive periodic acid-Schiff reaction (PAS positive) given by the secreted slime provided a means of localizing the secretion intercellularly. By observing the pathway light microscopically, secretion is tentatively established as outward, following the free space of the cell wall region after discharge from the symplast. Optimum movement rates were maintained only in saturated water atmospheres. A larger accumulation of Golgi product was found in cells of roots grown under water stress (conditions where external secretion was prevented). Upon transfer to water, external slime accumulation appeared. Under these conditions, electron microscopy verifies that secretion vesicles seldom accumulate in large amounts at the interior wall surface. This process exhibited a Q_{10} smaller than two, suggesting that extrusion of slime is not an active process but influenced by the increased turgor.

A tentative method for slime isolation has been developed, and chemical characterization is under way.

Work supported in part by NSF GB-1084.

Evidence for Secretion of Cell Dispersing Enzymes from Maize Root Cap and Epidermis. DAWN HALL, H. H. MOLLENHAUER and D. J. MORRÉ, Purdue University and C. F. Kettering Research Laboratory, Yellow Springs, Ohio.—Normal sloughing of root cap cells has been assumed to occur primarily through a dissolution of the intercellular cementing materials. Except for hypertrophy of the Golgi apparatus and associated secretory activity, the separating cells show normal ultrastructural patterns. They have turgid protoplasts surrounded by a continuous wall layer. Voeller (The Cell, Brachet and Mirsky, eds. VI, p. 274, 1964) suggested that the Golgi apparatus secretion vesicles of the outer root cap cells of maize might contain a cell wall hydrolyzing enzyme which would aid in separation and eventual breakdown of the cap cells. Secretion of digestive enzymes has not yet been shown to be a Golgi apparatus function in plants as it has in animal cells.

An assay based on dispersion of cucumber pericarp was used to measure cell dispersing enzyme activity along the root axis. Uniform tissue blocks prepared from mature cucumber fruits were incubated either with intact root pieces or with enzyme preparations. Dispersion activity was based on the amount of cell separation during standard test conditions. Cell separation was proportional to concentration of pectinase and other commercial cell wall hydrolyzing enzymes. Pectinase is also active in separation of root cap cells.

Preliminary results using the cucumber assay method indicate cell dispersing enzymes as components of maize root cap and root hair secretions. The root hair zone showed the greatest activity. Results will be discussed in relation to normal development of the root cap and root hair formation.

Work supported in part by NSF GB 1084, a contract with the U. S. Army Biological Laboratories and NSF Undergraduate Research Program G 22780.

Cytogenetics of Radiation-induced Chromosomal Aberrations in *Collinsia heterophylla* Buist. M. AKHTARUZZAMAN and K. S. RAI, University of Notre Dame.—Seedlings of *Collinsia heterophylla* at the cotyledon stage were gamma-irradiated at doses ranging from 1050-1600r. A tetraploid, a triploid, three trisomics and 13 reciprocal translocations were detected in the parental generation(X_1). Of these aberrations, the behavior of reciprocal translocations was followed in details in sequential generations.

In a few cases, chromosomal chimeras were observed in X_1 generation. One of the two branches of a plant, for example, was tetraploid and the other was normal, disomic. Chimeras in plants heterozygous for reciprocal translocations were also observed in a few cases.

Twelve of the reciprocal translocations involved two chromosome pairs and the remaining one, three pairs. Chromosome orientation at metaphase-1 in majority of the translocation heterozygotes was directional and occurred more frequently as rings than chains in most cases. Chiasma-frequency was higher for chromosomes involved in the reciprocal translocations. The pollen-stainability and seed-set in translocation heterozygotes varied from 50-95% and 22-95% respectively. Approximately 10-25% of the pollen-mother-cells in some translocation heterozygotes disclosed seven bivalents only.

Studies of chromosome association at metaphase-1 in the triploid and the tetraploid plants indicated that disjunction in these, too, was directional.

Inheritance of Stem Rust Resistance in *Avena sativa* L.[1]

FRED L. PATTERSON and SCOTT K. GILBERT, Purdue University

Five genes (A, B, D, E and F) for resistance to stem rust of oats caused by *Puccinia graminis* Pers. f. sp. *avenae* Erikss. and Henn. are widely recognized. McKenzie and Green (7) recently summarized the races and sub-races to which each gene confers resistance. Genes A, B and F appear to be closely linked or pseudo-alleles (1, 5, 6). A and D have been recombined with very little crossing over between them (5). Apparent recombinations between genes F and A have been found but true breeding lines have not been isolated (6). Genes B and E are inherited independently of each other and of the A-D-F complex. Unfortunately in most breeding materials genes A, D and F are linked in repulsion.

Irradiation has been utilized in the search for additional sources of resistance to stem rust. Frey and Browning (3) obtained 61 mutant strains after treating the Huron oat variety with X-ray. Konzak (4) reported a dominant mutant gene conferring resistance to race 7A of stem rust from treatment of the Mohawk oat variety with thermal neutrons. The danger of outcross contamination following irradiation has been pointed out (2).

The inheritance of two variant resistances obtained following treatment of the Clintland variety of oats with the chemical mutagen diepoxybutane are presented.

Materials and Methods

Clintland spring oats, with D resistance, were treated with 1:2, 3:4-diepoxybutane. One ml of aqueous solution of the mutagen was hypodermically injected into the culms near the developing panicle primordia at the premeiotic to early post-meiotic stages after the method of Murphy and Patterson (8). Four concentrations of the chemical, .005, .010, .050 and .100%, in water were used. All panicles were bagged to exclude contaminating pollen and the treated plants were isolated in a screen house on the Purdue campus with no other oat plants in the area.

The first and second selfed generations were grown in isolated disease nurseries with Clintland serving as the susceptible spreader for race 7 of stem rust to avoid pollen contamination. A heavy epidemic of barley yellow dwarf virus occurred in the first generation so all panicles producing seed were saved and utilized for growing the second generation. Four lines, tracing back to 2 of 239 original treated plants, were found to be homozygous for resistance to race 7 in the field in the second generation. For genetic studies the variants are referred to as 1 and 2a, 2b and 2c or when data are combined, as variant 1 and variant 2 based on origin.

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The variants were compared to varieties of known genetic resistance for seedling reactions in the greenhouse to races 6, 7, 7A and 8 of stem rust. Inheritance of resistance of the variants were studied following crosses of the variants with varieties with resistance genes A, B, D, and F. Seedling reactions of progenies were studied in the F$_2$ and F$_3$ in the greenhouse at an average temperature of about 75°F. Spores were transferred directly from stock pots by shaking. Seedlings were incubated overnight and reactions were determined on a 0 to 4 scale about 14 to 16 days after inoculation. For genetic studies reactions 0, 1 and 2 were considered resistant and 3 and 4 susceptible.

Results

Resistance of Variants

The variant lines were compared with differential varieties and parent lines for breadth of race protection as the first step in classifying the resistance in the variants (Table 1). The variants were similar to each other and were similar to Newton (gene A) across the 4 cultures which identify genes A, B and D. The variants exhibited a greater necrosis around the pustules than Newton, indicating a possible genetic difference, but not much more than Mo. 0-205 also carrying gene A.

TABLE 1
Seedling reactions to stem rust of induced variants and varieties of oats.

Variety	Resistance type	Race 6	7	7A	8
Variant 1	?	4	1	1	4
Variant 2a	?	4	1	1	4
Variant 2b	?	4	1	1	4
Variant 2c	?	4	1	1	4
Newton	A	4	1+	1+	4
White Tartar	D	4	4	4	1+
Canuck	B	1	1	4	1
Clintland	D	4	4	4	
Clintland 60	BD		1—	4	
Cartier	None		4	4	
Mo. 0-205	A		1	1	
Goodfield	AB		1—		
Purdue 5650	ABD		1—		
Kherson 27	F		1		

Inheritance of Resistance in F$_2$

The F$_2$ seedling reactions were studied following crosses of the variants with varieties of known genotypes to determine the inheritance of resistance in the variants (Table 2). In the crosses of variant 2 to the Clintland (D) variety from which it was derived, the resistance of variant 2 behaved as a single factor dominant to gene D in tests to races 7 and 7A.

Clintland 60 (BD) is resistant to race 7 and susceptible to race 7A. In the cross of variant 2 with Clintland 60, resistance of variant 2 to race 7 behaved as a simple dominant factor and the B resistance as a recessive, common at higher temperatures, suggesting a 13:3 ratio. In tests to race 7A, resistance behaved as a single dominant factor.

In crosses of variant 1 and variant 2 with Cartier (susceptible), resistance to race 7A appeared to be governed by a single dominant factor. No segregation occurred in crosses of variant 1 or variant 2 with varieties containing resistance A.

In crosses of variant 2 with Kherson 27 (F) all F_2 plants were resistant.

TABLE 2

Stem rust reactions of F_2 seedlings in crosses of variants 1 and 2.

Cross	Test race	Number of F_2 plants		P value for 3:1 ratio
		Resistant	Susceptible	
Clintland (D)	7	68	24	.80-.90
X Variant 2	7A	63	17	.30-.50
Clintland 60 (BD)	7	86	15	.30-.50*
X Variant 2	7A	55	19	.80-.90
Cartier (Susc.)				
X Variant 1	7A	28	10	.80-.90
Cartier (Susc.)				
X Variant 2	7A	13	5	.70-.80
Mo. 0-205 (A)				
X Variant 1	7	14	0	
Goodfield (AB)				
X Variant 1	7	42	0	
Purdue 5650 (ABD)				
X Variant 2	7	54	0	
Kherson 27 (F)				
X Variant 2	7	51	0	

* P value for 13:3 ratio. Resistance of BB is recessive at higher temperatures.

These limited F_2 data suggested that variant 1 and variant 2 possess a single dominant factor for resistance to races 7 and 7A of stem rust. The resistance may be the same as gene A, an allele to A, or a pseudo-allele to genes A and F from changes at the D locus. Studies were carried to the F_3 families to examine these possibilities. The variants did not possess the D resistance of the parental variety from which they were derived, so some type of change at this locus is involved.

Inheritance of Resistance in F_3

Because of the small number of F_2 families available in crosses of variants 1 and 2 with Clintland (D) and Cartier (susceptible), within family analyses were used in F_3 (Table 3). In all cases the resistance of variant 1 and variant 2 behaved as a simple dominant in tests to race 7, supporting the F_2 analyses.

In the cross of Clintland 60 (BD) with variant 2, 65 families were resistant, 51 were segregating and 13 were susceptible suggesting a 7:8:1 ratio (P value of .02-.05). This interpretation is based on the independent inheritance of the single factor resistance in variant 2 from factor B and that the heterozygote Bb is susceptible at the higher greenhouse temperatures as has been previously observed.

In crosses of variant 1 and variant 2 with Purdue 5650 (ABD) no segregation for susceptibility was detected in 141 F_2 families with a total of 3578 F_2 seedlings when tested to race 7. This supported the interpretation of F_3 data that no segregation occurred when the variants were crossed to varieties possessing resistance type A.

TABLE 3

Segregation of F_3 oat seedlings within F_2 families for resistance to race 7 of stem rust.

Cross	No. of F_2 families	No. of F_3 seedlings		P value for 3:1 ratio
		Resistant	Susceptible	
Clintland (D) X Variant 1	8	206	68	.90-.95
Clintland (D) X Variant 2	23	325	110	.80-.90
Cartier (susc.) X Variant 1	1	6	3	.50-.70
Cartier (susc.) X Variant 2	13	258	79	.50-.70

The relation between gene F and the single factor resistance in the variants was studied in crosses of Kherson 27 (F) with variant 1 and variant 2 with F_3 seedling tests to race 7 (Table 4). Rare crossovers apparently occurred between gene F and the single factor resistance of the variants. The crossover events resulting in susceptible plants are those which would be recovered in this test. One must interpret these type recombinants with caution since cytological abnormalities resulting in the loss of a critical chromosome segment would result in susceptible plants. A more critical test would be the isolation of recombinants in segregating families carrying both resistance factors. At the time of this research sub-races were not yet available to detect these recombinants.

Assuming that susceptible plants are true recombinants, the crossover event occurred in 3 of 334 gametes leading to the 167 F_2 plants for about 0.90% crossing over.

Assuming the resistance factor in the variants 0.9 crossover units from gene F, one can examine its relationship with genes A and D. Gene order of A, D and F has not been established. Koo *et al.* (5) estimated that A and D were closely linked in the coupling phase in C.I. 7098. McKenzie and Green (6) in an analysis in the repulsion phase estimated that A and D were about .15 units apart, in essential agreement with the previous report. A and F were estimated .06 units apart in the repulsion phase (6). These data on the linkage of the variant resistance with gene F indirectly support the data of McKenzie and Green (6) that F is closely linked with A and D.

TABLE 4

Tests for allelism between resistances of variant 1 and variant 2 with gene F.

Cross	No. of F_2 families			No. of F_3 seedlings
	Res.	Seg.	Susc.	
Kherson 27 (F) X Variant 1	22	0	0	330
Kherson 27 (F) X Variant 2a	44	1*	0	1039
Kherson 27 (F) X Variant 2b	27	2**	0	616
Kherson 27 (F) X Variant 2c	71	0	0	1599

* One susceptible plant in 40.

** One susceptible plant in 15 in one family and 3 susceptible plants in 15 in the other.

Since the function of gene D was lost in the variants, the variant resistance logically is a mutant at the D locus. The alternative explanation is that mutations occurred at 2 loci, D to d and a to A′. In the F_3 tests of Purdue 5650 (ABD) X variants no crossovers were detected. The presence of gene B reduces the precision in detecting crossovers between A and A′. The detection of susceptible recombinants would have established A′ at locus D.

The possibility that the resistance of the variants is type A without mutation cannot be completely examined because progeny of the original treated plants are not available. Other treated tillers of the two original plants producing variants did not produce seed in the first generation isolation nursery. The original plants would have needed to contain resistances AD or AB to be resistant to race 8 and to have mutated for D or B. Since the resistance of the variants was true breeding, outcrossing in the field disease nurseries can be excluded as a possibility.

The original treated plants were isolated and bagged excluding outcrossing as a possibility at this stage.

Intercrosses of variant 1 and variant 2 have not been made to establish the assumption that they are similar based on identical reaction to races of stem rust and similar breeding behavior.

Discussion

A major consideration is whether irradiation has produced a new source of resistance. Additional tests of variant 1 and variant 2 have been made by B. J. Roberts of the Cooperative Rust Laboratory, University of Minnesota. They were tested by numerous isolates of races 2, 5, 6A, 6F, 6AF, 7A, 8A, 8AF, 10A and 13A of oat stem rust in 1964-65 and found to react identically to Richland (A) and Andrew (A).

With genes A, D and F closely linked or pseudo-alleles genetic tests to prove that the variant resistance is a mutant at locus D are impractical. Analyses must be based on the occurrence of susceptible plants and cytological irregularities may confuse the interpretation.

With the resistance in the variants linked in repulsion with genes A, D and F, its utility in plant improvement is greatly reduced.

Summary

Two variant resistances were obtained following treatment of Clintland oats with the chemical mutagen diepoxybutane. The 2 variants appeared identical to gene A in resistance to various races. Genetic tests indicated that the resistance was closely linked to gene F in the complex A-D-F region.

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CHEMISTRY

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Metal-Metal Halide Reaction Products as Low Pressure Olefin Polymerization Catalysts

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Introduction

The polymerization of olefins, particularly ethylene, propylene, and isoprene was shown to yield variations in polymer structure depending upon the composition of the Ziegler catalyst (6). Of particular interest was the fact that polyethylene could be prepared from catalysts having cationic character although prepared from organo metals.

The results obtained previously indicate that pseudo-cationic systems containing no organo-metal may be useful catalysts for polymerizing ethylene and that solid polyethylene might be obtained instead of the usual oils.

In the experiments reported in the previous paper (6), organo-metals were present in the polymerization system. This was demonstrated by separating the solid phase of the Ziegler catalyst from the liquid which contained the soluble organo-metals. Neither component has catalytic activity, but when recombined performed normally.

To evaluate the possibility that pseudo-cationic systems could initiate olefin polymerization, a number of metal-metal halide reaction products were evaluated. Typical metals are sodium, magnesium, aluminum, titanium, iron, nickel, and cobalt. Typical metal halides are titanium tetrachloride, titanium trichloride, titanium dichloride, and zirconium tetrachloride.

Experimental Preparation of Catalysts

Method A

The metal and the metal halide were placed into a small flask fitted with a reflux condenser and a nitrogen inlet. The liquid phase usually consisted of the metal halide although, in some cases, inert solvents were also employed as a liquid medium. After refluxing for twelve to sixty hours, the catalyst was transferred to the polymerization vessel and pressured with ethylene to 500-1000 psi at temperatures ranging from room temperature to 200°. In some cases, the excess metal halide was removed by distillation or extracted by hydrocarbons.

Method B

To eliminate the difficulties encountered in washing, a furnace was constructed as shown in Figure 1.

A nitrogen stream swept $TiCl_4$ vapor over hot metals while subliming out volatile halides.

Method C

To demonstrate the ease of preparation of the new catalyst systems used in the course of this research, and to utilize the advantages resulting from decreased particle size and increased surface area, ballmilling was used as effective method for the preparation of catalysts directly from the metal and metal halide.

Method D

This method consisted in preparing the catalyst *in situ* by introducing the metal-metal halide and solvent into the polymerization vessel directly and allowing the catalyst reaction to occur in the vessel, followed by polymerization in the same unit.

Method E

In this method, catalysts were prepared by disproportionation. The metal halide can be rendered active either by heating or by grinding in a ballmill.

Polymerization

Ethylene

Titanium Dichloride (Method D). Titanium dichloride, 1.0 grams, in 50 ml of redistilled dry n-heptane was charged to a stainless steel bomb and pressured with ethylene at 500 psi at 150° for 12 hours. Upon cooling and venting, a trace of white powder whose infrared spectrum was that of low molecular weight polyethylene was obtained.

Method E

When 7.45 grams of titanium dichloride was ballmilled in xylene and the polymerization carried out under the same conditions, the bomb became plugged with solid polyethylene. During grinding, $TiCl_2$ disproportionates to titanium and titanium tetrachloride (1).

Titanium Trichloride (Method D). The attempted polymerization of ethylene using the same conditions for $TiCl_2$, yielded no polymer.

Titanium Mono-Oxide (Method D). When titanium mono-oxide was used under the conditions described for $TiCl_2$, only a trace of polyethylene was obtained.

Titanium Mono-Oxide and Sodium (Method D). A catalyst prepared by reacting sodium (1 ml of a 50% dispersion) and 6.8 grams of titanium mono-oxide under the same conditions, yielded only a trace of polyethylene.

Titanium Metal (Method D). No solid polymer was obtained when 25 grams of titanium metal was used alone under the conditions described for $TiCl_2$ although, a trace of low melting wax was obtained by evaporating toluene which was used as a dispersing medium.

Titanium and Titanium Tetrachloride (Method A). Titanium, 8.65 grams (180 mgatom) was refluxed with 10 ml (91.1 mmoles) of titanium tetrachloride for 12 hours. The reaction product was washed several times with dry toluene and the toluene distilled off. The washed reaction product in 80 ml of freshly distilled dry toluene was charged to the bomb pressured to 850 psi with ethylene and heated to 175°C for 20 hours. The yield of solid polyethylene was 100.95 grams.

Titanium and Titanium Tetrachloride (Method E). To compare the reactivity of the previous catalyst as related to method of preparation, 8.65 grams (180 mgatom) of titanium and 10 ml (91.1 mmoles) of titanium tetrachloride were ballmilled for 60 hours and charged to a bomb containing 80 ml of redistilled dry toluene. Ethylene was pressured to 500 psi and the bomb heated to 125°C for 18 hours. As a result, 14.4 grams of solid polyethylene was obtained.

Titanium and Titanium Tetrachloride (Method B). Titanium (10 grams) was heated to 450°C in a furnace (Figure 1) while passing a nitrogen stream containing $TiCl_4$ vapor through the metal for five hours. Upon cooling, the reaction product was charged to the bomb containing 80 ml dry redistilled toluene, pressured to 500 psi with ethylene and heated to 125°C for 16 hours. Upon cooling, 50 grams of solid polyethylene was obtained.

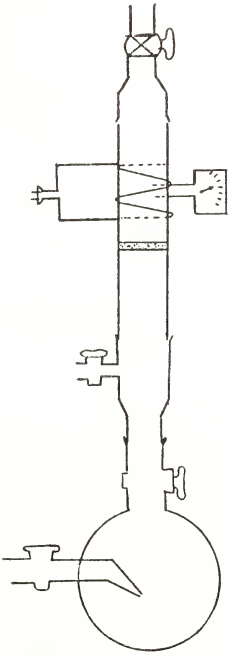

Figure 1

Titanium and Titanium Tetrachloride (Method B). The previous experiment was repeated except that no solvent was used for the polymerization. Upon opening the bomb, polyethylene was observed which had grown directly from the gas phase onto the catalyst surface. Upon extraction with boiling xylene, 2.1 grams of polyethylene was obtained (3).

Aluminum and Titanium Tetrachloride (Method A). Aluminum (10 grams) and 10 ml of titanium tetrachloride was refluxed for 12 hours in chlorobenzene at 111°C. Ethylene was then passed through the mixture at 0.5 liters/minute for 5 hours at atmospheric pressure. From this reaction, 8.0 grams of solid polyethylene was obtained.

Aluminum and Titanium Trichloride (Method C). Aluminum metal, 0.5 grams, and 2.0 grams of titanium trichloride were ballmilled for 8 days. The dry pyrophoric catalyst, 0.5 grams, was transferred to the bomb in a dry box sealed, pressured with ethylene at 500 psi and heated to 100° for 19 hours. On cooling, 0.2 grams of solid polyethylene was obtained which had grown directly on the catalyst surface.

Other examples are given in Table I through Table IX.

Propylene

Aluminum and Titanium Tetrachloride (Method B). Ten grams of aluminum metal were heated for 5 hours in a furnace (Figure 1) while passing a nitrogen stream containing $TiCl_4$ vapor over the metal. The reaction product was then cooled and transferred to the bomb containing 80 ml redistilled dry n-heptane. Propylene was pressured to 140 psi and the bomb heated to 75° for 48 hours. As a result, 10.5 grams of solid polypropylene was obtained.

Titanium and Titanium Tetrachloride (Method D). Titanium, 8.65 grams and 10 ml of titanium tetrachloride reaction product were charged to the bomb containing 80 ml redistilled dry heptane. The bomb was heated to 60° and pressured with propylene at 100 psi and the reaction carried out for 36 hours; 13.4 grams of solid polypropylene was obtained.

Several other examples are given in Table VIII.

Isoprene

A number of representative metal-metal halide reaction products were evaluated as catalysts for the polymerization of isoprene and the data is summarized in Table IX. In this case, only resinous cationic-type polyisoprene were obtained.

Discussion

Metal of Group I did not yield active catalyst when reacted with the metal halides shown in Table I. The reaction of sodium and titanium tetrachloride proceeds rapidly forming a black solid mixed with sodium chloride. This catalyst was inactive but when ground in a ballmill, became active by disproportionation. This has been recently repeated by Machida who prepared the catalyst by Method C (4) and by Matlack and Breslow (5).

Catalysts prepared from Group II metals and the titanium halides did not yield solid polymers. Washing excess titanium halide from the solid catalyst did not enhance catalyst activity.

Of the Group III metals, the catalyst derived from boron and $TiCl_4$ was inactive under the experimental conditions tried, while all the catalysts prepared from aluminum and titanium and zirconium halides were active except potassium hexachlorotitanate. Aluminum-aluminum chloride reaction product was subsequently shown to be active when ballmilled (2).

Unlike aluminum, titanium reacted with potassium hexachlorotitanate (Table IV) to produce an active catalyst. The titanium-titanium halide systems are of the same order of activity of the aluminum-titanium halide system. Of particular interest is the catalyst produced by the vapor phase reaction of titanium and butyl chloride.

Catalysts produced from elements of Group V and VI were not very active under the conditions studied, while those from the elements of Group VII, particularly when chlorinated, produced high yields of polymer.

In Group VIII iron, cobalt, and nickel reduced titanium and zirconium halides to active catalyst; iron being the poorest reducing metal for titanium tetrachloride.

Conclusion

The results obtained in these studies clearly indicate that organo metals are not required to prepare active olefin polymerization catalysts. The catalysts described in this paper may be prepared by several methods and from readily available chemicals.

That the nature of the catalyst is cationic in character was shown by the products obtained from propylene and isoprene. Polypropylene and polyisoprene were similar to those obtained with Ziegler catalysts when the catalyst component ratio was high in Lewis Acid.

Titanium was more effective than aluminum in preparing an active catalyst from K_2TiCl_6. At atmospheric pressure, aluminum produced a more active catalyst with $TiCl_4$ than did titanium.

The presence of excess metal halide reduces the yield of solid polymer. This was demonstrated by extracting with hydrocarbon or subliming excess metal halides during catalyst preparation. When this operation was performed, higher yield of polymers were obtained.

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TABLE I
Ethylene Polymerization Catalysts Prepared Using Group I Elements

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
Na + $TiCl_4$	A	Toluene	60°; 12 hrs.	Trace of polymer
Na + $TiCl_4$	A	Chlorobenzene	80°; 6 hrs.	None
Cs + VCl_3	D	Toluene	125°; 500 psi 12 hours	None

TABLE II
Ethylene Polymerization Catalysts Prepared Using Group II Elements

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
Mg + $TiCl_4$	D	Toluene	125° 1 atm; 18 hrs.	Oil
Mg + $TiCl_4$	C	Toluene	125° 500 psi; 20 hrs.	None
Zn + $TiCl_4$	A	Toluene	60° 1 atm; 24 hrs.	Oil
Zn + $TiCl_4$	C	Toluene	100° 500 psi; 18 hrs.	Oil
Zn + $TiCl_4$	B	Xylene	175° 500 psi; 26 hrs.	Viscous oil
Zn + $TiCl_3$	C	Xylene	100° 500 psi; 72 hrs.	Oil
Zn + $TiCl_4$ + $AlCl_3$	A	Toluene	60° 1 atm; 18 hrs.	Oil and wax
Hg + $TiCl_4$	C	Toluene	125° 500 psi; 24 hrs.	Oil
Hg + $TiCl_3$	A	Toluene	125° 500 psi; 6 hrs.	Viscous oil

TABLE III
Ethylene Polymerization Catalysts Prepared Using Group II Elements

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
B + $TiCl_4$	A	Toluene	111° 1 atm; 12 hrs.	None
Al + $TiCl_4$	A	Toluene	111° 1 atm; 7 hrs.	Oil
Al + $TiCl_4$	A	Chlorobenzene	111° 1 atm; 5 hrs.	8.0 g. solid
Al + $TiCl_4$	B	Toluene	125° 850 psi; 16 hrs.	71.6 g. solid
Al + $TiCl_4$	C	None*	125° 1000 psi; 72 hrs.	1.2 g. solid
Al + $TiCl_2$	C	Toluene	125° 500 psi; 18 hrs.	54.8 g. solid
Al + $TiCl_3$	C	Toluene	100° 500 psi; 18 hrs.	49.7 g. solid
Al + $AlCl_3$	C	Toluene	50° 1 atm; 3 hrs.	None
Al + Ti + $AlCl_3$	C	Toluene	100° 500 psi; 4 hrs.	14.0 g. solid
Al + $AlCl_3$ + $TiCl_4$	C	Toluene	100° 500 psi; 4 hrs.	94.7 g. solid
Al + $ZrCl_4$	C	Toluene	100° 500 psi; 12 hrs.	4.6 g. solid
Al + K_2TiCl_6	C	Heptane	100° 500 psi; 12 hrs.	None
Al + $TiCl_2$**	C	Toluene	175° 1100 psi; 16 hrs.	20.0 g. solid

* This catalyst was placed into the dry bomb and the monomer was polymerized directly on the surface from the gas phase.

** $TiCl_2$ was obtained from the reaction of Na and $TiCl_4$ in chlorobenzene. This experiment proves that sodium does reduce $TiCl_4$ to $TiCl_2$ and probably explains the reason for the inactivity of the Na-$TiCl_4$ system.

The catalysts prepared using aluminum and titanium halides by ball-milling were the most active and the easiest to prepare. The formation of bimetal complexes may be responsible for the high activity of the catalysts.

TABLE IV
Ethylene Polymerization Catalysts Prepared Using Group IV Elements

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
Ti + $TiCl_4$	C	Toluene	125° 500 psi; 18 hrs.	14.4 g. solid
Ti + $TiCl_4$	B	None*	125° 500 psi; 20 hrs.	2.1 g. solid
Ti + $TiCl_4$ + BuCl**	B	Toluene	100° 500 psi; 14 hrs.	20.0 g. solid
Ti + BuCl	B	Toluene	125° 500 psi; 18 hrs.	1.9 g. solid
Ti + $SbCl_5$	A	Toluene	111° 1 atm; 6 hrs.	Oil
Ti + $SbCl_5$	B	Toluene	150° 250 psi; 12 hrs.	2.1 g. solid
Ti + $TiCl_2$	C	Toluene	125° 500 psi; 24 hrs.	None
Ti + $TiCl_3$	C	Toluene	125° 500 psi; 96 hrs.	59.3 g. solid
Ti — Al + $TiCl_4$***	B	Toluene	125° 1000 psi; 12 hrs.	30.0 g. solid
Ti + K_2TiCl_6	B	Xylene	170° 1000 psi; 20 hrs.	1.1 g. solid
Ti + $AlCl_3$	B	Toluene	125° 500 psi;20 hrs.	10.0 g. solid
Ti + $AlCl_3$	C	Toluene	125° 500 psi; 18 hrs.	6.7 g. solid
Ti + $ZrCl_4$	C	Toluene	130° 500 psi; 19 hrs.	3.5 g. solid

* This catalyst was placed into the dry bomb and the monomer was polymerized directly on the surface from the gas phase.

** One ml. of n-butyl chloride added to the solvent.

*** Ti—Al alloy of the approximate composition 55% Ti and 40-45% Al.

TABLE V
Ethylene Polymerization Catalysts Prepared Using Group V and VI Elements

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
Cr. + $TiCl_4$	A	Toluene	145° 600 psi; 16 hrs.	0.1 g. solid
Sb + $AlCl_3$	C	Heptane	100° 500 psi; 48 hrs.	Oil

TABLE VI
Ethylene Polymerization Catalysts Prepared Using Group VII Elements

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
Ti + Cl_2*	B	Toluene	150° 600 psi; 12 hrs.	90.0 g. solid
Ti + I_2	C	Toluene	100° 500 psi; 12 hrs.	5.0 g. solid

* Halogenation of the metal was not complete and free metal exists in these catalysts.

TABLE VII
Ethylene Polymerization Catalysts Prepared Using Group VIII Elements

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
Fe + $TiCl_4$	A	Toluene	125° 500 psi; 48 hrs.	0.5 g. solid
Fe + $TiCl_4$	B	Toluene	100° 1 atm; 3 hrs.	Oils
Fe + $TiCl_4$	C	Toluene	125° 850 psi; 18 hrs.	Oils
Fe + $TiCl_2$	C	Toluene	125° 500 psi; 24 hrs.	11.0 g. solid
Fe + K_2TiCl_6	B	Toluene	80° 1 atm; 5 hrs.	Oils
Fe + $ZrCl_4$	C	Toluene	125° 500 psi; 24 hrs.	Oils
Ni + $TiCl_4$	C	Toluene	125° 500 psi; 48 hrs.	20.8 g. solid
Co + $TiCl_4$	C	Toluene	125° 500 psi; 48 hrs.	7.8 g. solid

TABLE VIII
Propylene Polymerization Catalysts

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
Na + $TiCl_4$	B	Heptane	75° 140 psi; 12 hrs.	Oil
Hg + $TiCl_4$	B	Xylene	100° 240 psi; 12 hrs.	Oil
Al + $TiCl_4$	D	Toluene	111° 1 atm; 12 hrs.	Oil
Al + $TiCl_4$	B	Toluene	115° 160 psi; 24 hrs.	Oil
Al + $TiCl_4$	B	Toluene	75° 140 psi; 16 hrs.	Trace solid
Al + $TiCl_4$	B	Heptane	75° 140 psi; 48 hrs.	10.5 g. solid
Al + $TiCl_4$	C	Heptane	100° 190 psi; 20 hrs.	52.8 g. solid
Al + $AlCl_3$ + $TiCl_4$	C	Toluene	25° 170 psi; 12 hrs.	0.9 g. solid + oil
Ti + $TiCl_4$	D	Toluene	175° 220 psi; 24 hrs.	Oil
Ti + $TiCl_4$	B	Heptane	75° 140 psi; 72 hrs.	15.0 g. solid
Ti + $TiCl_4$	D	Heptane	60° 100 psi; 36 hrs.	13.4 g. solid

TABLE IX
Isoprene Polymerization Catalysts

Catalyst Components	Method of Preparation	Solvent	Polymerization Conditions	Product Obtained
Al + $TiCl_4$	A	Toluene	25°; 5 hrs.	Resin
Tl + $TiCl_4$	B	Heptane	60°; 24 hrs.	Resin
Ti + $TiCl_3$	C	Toluene	40°; 12 hrs.	Short rubber

Variations of Polymer Structure with Catalyst Composition in Ziegler Type Polymerizations

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Introduction

The discovery of the Ziegler catalyst (4) for polymerizing olefins, particularly ethylene, created intense academic and industrial interest. Prior to this discovery, polymers of ethylene consisted of oils prepared by Lewis acid catalyzed polymerizations or solid low-density polyethylene prepared at very high pressures using traces of oxygen as a free radical catalyst.

A typical Ziegler catalyst can be prepared by coreacting mole for mole, an aluminum alkyl and a metal halide such as titanium tetrachloride in a hydrocarbon forming an intensely colored heterogeneous solid catalyst. Polymerization of ethylene at room temperature and at atmospheric pressure is rapid (5).

The polymerization of ethylene by these heterogeneous catalysts was not easily explained by a free radical mechanism. Ziegler (1) suggested that the polymerization may occur by an anionic mechanism. Furthermore, the catalyst component ratio can be varied and still yield solid polyethylene suggesting that the catalyst structure may vary and may have an effect on the structure of the polymer. A detailed study of selected catalyst ratios was undertaken to obtain more information about the catalyst and to discover a possible mechanism of the polymerization.

Titanium tetrachloride is a Lewis Acid capable of initiating a cationic polymerization reaction, while triisobutyl aluminum, an organometal, is capable of initiating some anionic polymerizations. Therefore, if in the preparation of a Ziegler catalyst, an excess of either component is used above the stoichiometric amount required to prepare the catalyst, it may be possible for the resulting system to function either as a pseudocationic or a pseudo-anionic system.

The variation of catalyst structure over a selected ratio should affect polymer structure and yield, catalyst efficiency, monomer absorption rate, and should indicate the most efficient ratio for optimum polymer yield.

After establishing the Al/Ti ratio for ethylene, this data may be applied to other olefins to determine whether the change in composition of catalyst would indeed influence the structure of the polymer.

Ethylene is symmetrical and will not yield a polymer having stereospecific structure, but yield oligomers in the presence of Lewis Acids (2). However, propylene can produce polymers having three stereospecific conformations depending upon the type of polymerization catalyst. With Lewis Acids, atactic oligomers are usually obtained while with anionic catalysts, isotactic, syndiotactic, or atactic forms of polypropylene can be obtained. Similarly, the structure of the polyisoprenes are determined by the composition of the initiator yielding hard resinous cationic polymers, or rubbery polyisoprene with anionic catalysts. This should also hold true for Ziegler catalysts if their ionic character changes with composition.

Experimental

Ethylene

The following general procedure of Experiment No. 1 was used for all experiments using catalyst ratios listed in Table 1.

TABLE I

Mole Ratio of Catalyst Reactants for Ethylene Polymerization

Experiment No.	Millimoles AlR_3	Millimoles $TiCl_4$	Ratio Al/Ti
1	10.1	50.5	1:5
2	10.1	40.4	1:4
3	10.1	30.3	1:3
4	10.1	20.2	1:2
5	10.1	10.1	1:1*
6	10.1	0	—
7	0	10.1	—
8	20.2	10.1	2:1
9	30.3	10.1	3:1
10	40.4	10.1	4:1
11	50.5	10.1	5:1

* This catalyst ratio yields a catalyst having the composition indicated by the equation: $R_3Al + TiCl_4 \rightarrow R + R_2AlCl + TiCl_3$.

Into a two-liter autoclave containing 400 ml. of freshly distilled dry n-heptane was placed 5.55 ml. (50.5 mmoles) of titanium tetrachloride and 5.0 ml. (10.1 mmoles) of triisobutyl aluminum under a nitrogen blanket forming a typical Ziegler catalyst. The autoclave was flushed with nitrogen, stirring was started and the catalyst was aged for twenty-four hours at 60°.

Ethylene was then pressured to the autoclave at 300 psi with the stirrer off; stirring was resumed and the reaction was continued for twelve hours. Pressure drops were noted and recorded. Upon completion of the reaction, the autoclave was cooled, the excess gas vented, the autoclave opened under a nitrogen blanket, and the color of the reaction mass noted. The contents of the autoclave were poured into 200 ml. of methanol containing 1% of hydroquinone as an antioxidant. The solids were stirred in methanol for several hours prior to filtering, washing, and drying to afford 4.87 g. of polyethylene which melted at 125°.

The methanol and heptane layers were separated using a separatory funnel, and each layer was concentrated under a vacuum and the residues distilled.

The heptane layer yielded 0.74 g. of a viscous oily residue, while the methanol layer yielded 2.5 g. of an oil distilling between 30-60° at 5 mm. and 1.0 g. of a tarry solid which when charred, yielded inorganic salts.

The results of these reactions are summarized in Table II.

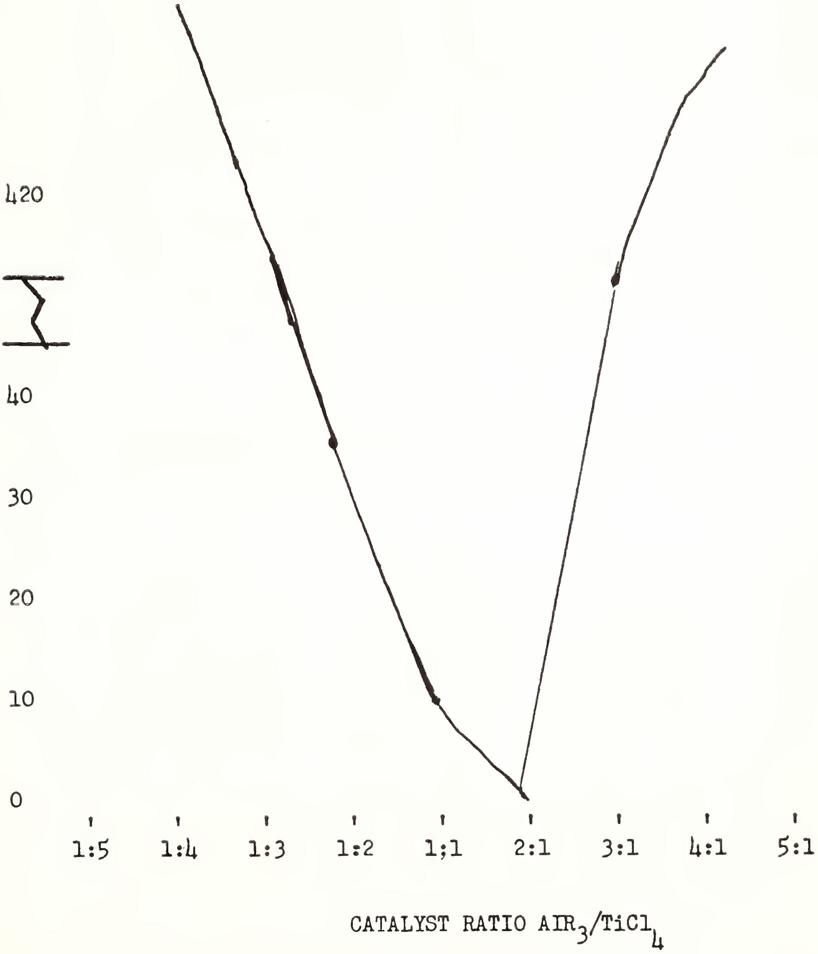

Figure 1. Disappearance of ethylene monomer with time.

The rate of disappearance of the monomer was noted on the basis of its variation with catalyst mole ratio, and the data obtained is listed in Table III and Figure 1.

TABLE II

Results of the Ethylene Polymerizations Using Various Al/Ti Ratios in Catalyst

Experiment No.	Al/Ti in Catalyst Ratio[a]	Color of Reaction Mass	Weight of Solid Polymer (g)	M.P. (°C) of Polymer	Weight of Product in Heptane[b] (g)	Weight of Product in Methanol[c] (g)
1	1:5	purple	4.87	125	0.74 oil	2.55 oil b.p. 30–60° 5mm 1.0 tar
2	1:4	purple	9.55	126.5	3.19 oil	1.0 tar
3	1:3	red-purple	14.6	131-132	1.10 oil	5.67 oil b.p. 70–72° 9.56 tar
4	1:2	dark-brown	16.11	124-125	1.41 oil	3.92 oil b.p. 70–72° 5.29 tar
5	1:1	light-brown	15.7	136-136.5	0.96 tar	8.78 oil b.p. 70–72° 2.8 tar
6	1:0	colorless	0.0	......	0.26 tar	......
7	0:1	colorless	0.0	......	2.1 tar	......
8	2:1	grey	15.6	137-138	1.35 oil	9.62 tar
9	3:1	black	16.0	138-139	0.69 tar	6.62 oil 1.42 tar
10	4:1	black	15.1	133-134	0.53 oil	6.42 tar
11	5:1	black	13.8	136-137	......	1.3 tar

a. The catalyst ratio is the ratio of triisobutyl aluminum to titanium tetrachloride in millimoles per liter.
b. The product obtained after concentrating the heptane layer.
c. The product obtained after concentrating the methanol layer.

TABLE III
Disappearance of Ethylene Monomer as Function of Catalyst Composition

Experiment No.	Minutes required for 0 pressure	Al/Ti Ratio[a]
1	more than 960 min	1:5
2	960	1:4
3	420	1:3
4	34	1:2
5	9	1:1
8	2	2:1
9	37	3:1
10	420	4:1
11	420	5:1

a. The ratio of triisobutyl aluminum to titanium tetrachloride.

Disappearance of the Monomer

Catalyst Efficiency

The catalyst efficiency calculated as the amount of polymer obtained per gram of catalyst is shown in Table IV. The maximum catalyst efficiency occurs at the 1:1 ratio of catalyst components.

TABLE IV
Catalyst Efficiency for Ethylene Polymerization

Al/Ti ratio in Catalyst[a]	Catalyst Weight(g)	Polymer Yield(g)	Catalyst Efficiency
1:5	11.6	4.87	0.42
1:4	9.7	9.55	0.99
1:3	7.8	14.6	1.86
1:2	5.8	16.0	2.76
1:1	3.9	15.4	3.93
2:1	4.9	11.6	2.37
3:1	7.9	16.0	2.06
4:1	9.9	15.1	1.52
5:1	11.9	13.8	1.16

a. The catalyst ratio is the ratio of triisobutyl aluminum to titanium tetrachloride.

Propylene

The procedure used for the polymerization of propylene was the same as that used for ethylene and is described above with the exception of the propylene was pressured to 100 psi.

The results of these experiments are listed in Table V.

TABLE V

Results of the Propylene Reactions using Catalyst Ratios

Experiment No.	Catalyst Ratio[a]	Color of Reaction Mass	Weight of Solid Polymer (g)	M.P. (°C) of Polymer	Weight of Product in Heptane[b] (g)	Weight of Product in Methanol[c] (g)
1	1:5	red-brown	....	......	5.56 oil	28.37 dark oil
2	1:4	reddish	....	......	9.35 oil	19.01 viscous oil
3	1:3	dark-brown	....	......	8.21 oil	5.8 tar
4	1:2	brown	....	......	10.1 oil	10.41 dark oil
5	1:1	mud-brown	5.7	159-161	0.42 wax	5.91 solids and tar
6	1:0	colorless	....	......	0.21 oil	6.64 oil, b.p. range 72-85
7	0:1	colorless	....	......	3.0 (ml) waxy oil	2.38 dark oil
8	2:1	black	7.37	110	......	7.57 tar
9	3:1	black	1.56	155	1.54	6.66 tar
10	4:1	black	0.21	145-146	0.09 tacky solid	0.09 solid (Al_2O_3) 21.13 tar
11	5:1	black	0.19	145-146	0.32 tacky solid	16.76 tar

a. The catalyst ratio is the ratio of triisobutyl aluminum to titanium tetrachloride.

b. The product obtained after concentrating the heptane layer.

c. The product obtained after concentrating the methanol layer.

Isoprene

The procedure used for the polymerization of isoprene is the same as that used for ethylene with the exception that 10 ml. of distilled liquid isoprene was added. The results are listed in Table VI.

TABLE VI
Results of the Isoprene Polymerization Reactions Using Various Catalyst Ratios

Al/Ti Ratio Catalyst[a]	Color of Reduction Mass	Weight of Solid Polymer(g)	Weight of Product in Heptane(g)[b]	Weight of Product in Methanol[c](g)
1:5	purple	0.22	3.21 resin	12.39 black tar
1:4	red-purple	....	4.40 resin	8.32 black tar
1:3	red-brown	3.38	0.23 resin	15.01 black tar
1:2	red-brown	0.19	3.86 resin terpene odor	4.87 black tar
1:1	red	latex 6.8	....	....
1:0	colorless	....	terpene oil	....
0:1	colorless	resin	....	....
2:1	black	0.91 rubber	3.71 oil	....
1:3	black	0.79 rubber	1.73 terpene oil	tar
4:1	black	0.36 rubber	0.5 terpene oil	tar
5:1	black	trace	trace terpene oil	tar

a. The catalyst ratio is the ratio of triisobutyl aluminum to titanium tetrachloride.

b. The product obtained after concentrating the heptane layer.

c. The product obtained after concentrating the methanol layer.

In order to complete and extend the study, the soluble portion of the Ziegler catalyst prepared at the Al/Ti 1:1 ratio was used to polymerize propylene and isoprene. At this ratio, dialkyl aluminum chloride would be present and should yield products typical of cationic initiation. Using the procedure outlined for ethylene, an oil was obtained with propylene and a short-rubber characteristic of a cationic initiation was obtained from isoprene.

Discussion

Ethylene

Several changes are noted when ethylene is polymerized using different Al/Ti ratios in the preparation of Ziegler catalysts.

The maximum rate of disappearance of monomer occurs at a catalyst component ratio of 1:1. Polyethylene yield and catalyst efficiency also approach a maximum at this ratio. The decrease in activity of the catalyst over or under Al/Ti ratio of 1:1 may indicate that the nature of the catalyst is being changed with an excess of either aluminum alkyl or titanium tetrachloride. The amount of heptane soluble oil was higher when excess titanium tetrachloride was used (Al/Ti ratio 1:4) than when excess aluminum alkyl was used. (Al/Ti ratio 4:1)

Changes in the color of the reaction mass were noted. As the catalyst composition increased in aluminum alkyl content, the color changed from purple to brown to black and remained black above an Al/Ti ratio of 2:1. This indicates that the solid phase of the catalyst changes in titanium trichloride content and above a Al/Ti ratio of 2:1 is predominantly titanium dichloride.

Propylene

The results of the propylene experiments are very much in accord with the proposal that a pseudo-anionic or pseudo-cationic mechanism may be operating depending upon the ratio of catalyst components. Particularly significant is the complete change in the nature of the product at an Al/Ti ratio of 1:1, which corresponds to the polymers obtained by known anionic systems. The melting point of polypropylene obtained at a ratio of 1:1 (159-161°C) is in agreement with the melting point of isotactic polypropylene.

Although the yields are not as well defined as those in the polyethylene case, the general trend toward a decrease in the yield of solid polymer with increasing Al/Ti ratio above 1:1 ratio is in general agreement with the data for ethylene.

Another point of general agreement is the color of the catalyst and the fact that above a ratio of 1:1 of Al/Ti a black color indicative of the formation of titanium dichloride, is obtained for each monomer. This may be explained by the reduction of the initial $TiCl_3$ (purple) to $TiCl_2$ (black) by excess aluminum alkyl. This was also shown by sodium reduction of $TiCl_4$ and sodium reduction of $TiCl_3$ (2).

Isoprene

The results obtained with isoprene are consistent with the theory developed using ethylene and propylene.

One interesting fact is the almost complete absence of rubber above a Al/Ti ratio of 2:1 is reached and the appearance of terpene oils. This may be explained by the appearance of a black catalyst as the ratio of catalyst components exceeds 1:1 and indicates the formation of titanium dichloride, which in the presence of triisobutyl aluminum was shown to be an inactive catalyst (2).

The change in the nature of the product from a resin to a rubber at Al/Ti ratio of 1:1 is in agreement with previous results obtained with propylene and indicates the ratio which yields the most active catalyst. At a catalyst component ratio of 1:1, Saltman (3) obtained rubber in high yields containing essentially cis 1,4 polyisoprene.

Conclusion

The data obtained by polymerizing ethylene propylene and isoprene at different Al/Ti ratios, indicates that the nature of the respective polymers obtained depends to a high degree on the component ratio.

Ziegler (4) reported that when solid and liquid phases of the catalyst were separated neither component was capable of initiating polymerization. This was confirmed by the present authors and by Saltman (3) who obtained similar results and showed that when the components were recombined catalyst activity was restored. This would indicate that both components, the organo-metal and the metal halide, are necessary for catalyst activity.

However, in these studies since some solid polymers were obtained by varying the Al/Ti ratio in the catalyst composition, it should be possible to prepare solid polyethylene from strictly ionic catalysts without the use of organo-metals.

A study of organo-metal free catalysts will be presented in the next paper.

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Anomalies in the Density Curves of Alkyldiamine-Water Systems[1]

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Introduction

The only previous works reported on alkyldiamine-water systems were those done by Elgort (1) in 1929, and Ust-Kachkintzev (6) in 1934, on the system ethylenediamine-water. Elgort's melting point curve indicated the existence of a monohydrate expressed as a distorted maximum, and a dihydrate as a concealed maximum. An opposite relationship occurred in the viscosity curve, where the dihydrate is a distinct maximum, and faint maximums occur corresponding to a monohydrate and semihydrate. The density isotherms occurred as convex curves with slight inflections at those positions corresponding to the three hydrates. Incomplete data in the 70-100 mole percent water region indicated a broad maximum and a possible minimum.

The purpose of this work was to determine density isotherms of several alkyldiamine-water systems in those regions where hydrate formation occurs, and to investigate further the apparent maximum found in the region of higher water concentration. From this data apparent molal volumes were calculated, considering both water and the alkyldiamine as solvents, and temperature effects on these relationships tested.

Experimental

The alkyldiamines used were Matheson, Coleman, and Bell and contained up to 3% water as the main impurity. They were dried by refluxing over calcium hydride for four hours, followed by distilling twice over fresh calcium hydride using an atmosphere of dry nitrogen. Due to the extreme hygroscopic nature of the alkyldiamines, stock solutions were prepared containing 5-10 weight percent water by direct distillation into a tared flask containing a known weight of distilled water.

Densities were obtained by means of an accurate Westphal-type balance. The balance was constructed from a Sargent model LCB chainomatic balance by replacing the left pan with a glass displacement bob suspended by a fine platimum wire through a hole drilled in the balance table. The balance was mounted over a water bath thermostatically controlled to ±0.005°C by a mercury thermoregulator. The stock alkyldiamine-water solution was placed in a sample flask, and the weight of the displacement bob recorded after thermal equilibrium had been reached. Water was then added by means of a weight burette in quantities such that the density could be taken in intervals of 1-2 weight percent water. Stock solutions were used immediately after preparation, and fresh glass-distilled water was used, thus eliminating

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[1] This investigation has been supported by the Atomic Energy Commission under contract No. AT(11-1)-256.

gas bubble formation. Duplicate runs were made in all cases, and values agreed within ±0.00005 gm ml^{-1}.

All weights taken with the chainomatic balance were corrected for air bouyancy and the surface tension effect on the platinum wire was found to be negligible.

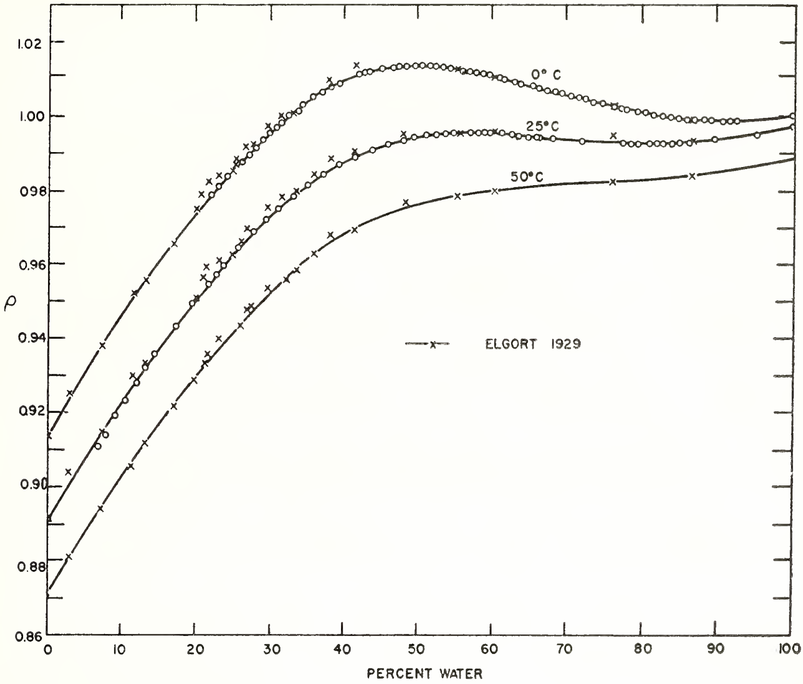

Figure 1. Plot of density in gm ml^{-1} vs. weight percent water for ethylenediamine-water mixtures.

Results and Discussion

Density isotherms for ethylenediamine-water mixtures at 0[2], 25, and 50°C are shown in Figure 1. The maximums reported by Elgort corresponding to the proposed hydrate formations were not found in our data, and replicate runs failed to indicate their existence. A pronounced maximum does occur which shifts to higher water percentage regions as temperature increases, and becomes more pronounced as temperature is decreased. A distinct minimum is present in the 25°C isotherm, but is not evident in the 0° or 50° isotherms.

To determine if the effect was due to hydrogen-bonding between water and the nitrogens in the alkyldiamine, a series of densities were taken for ethylenediamine-methyl alcohol mixtures at 25°C. The result was a smooth convex curve displaying no pecularities for the entire range. To determine the effect of the structure of the alkyldiamine, densities were taken for methylethylenediamine and trimethylenediamine-water mixtures at 0° and 25°. These results are shown graphically in Figure 2. In both cases the results are similar to those for the ethylenediamine-water isotherms, with the maximum being reduced in amplitude and shifted to the higher water percent region.

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[2] Data at 0°C was partially taken by Charles Bronick of this laboratory.

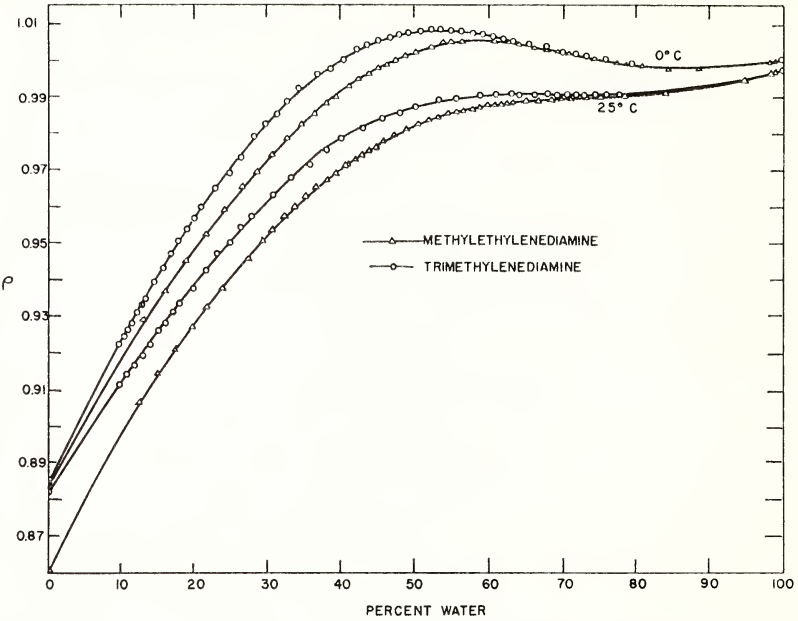

Figure 2. Density vs. weight percent water for methylethylenediamine and trimethylenediamine water mixtures at 0° and 25°.

In order to understand more fully the significance of the density isotherms, the apparent molal volumes were calculated, both for water and the alkyldiamines as solvents. The apparent molal volume, Φ_{V_2}, can be calculated from the relationship,

$$\Phi_{V_2} = \frac{1000\ (d_o - d)}{m d_o d} + \frac{M_2}{d},$$

where d_o is the density of the pure solvent, M_2 is the molecular weight of the solute, and d is the density of the solution at a concentration m, in molality. The major source of error in apparent molal volumes arises from the $(d_o - d)$ term in the equation. Slight errors in either d_o or d at low concentration will cause a large deviation in Φ_{V_2}. The densities used in our calculation for the pure alkyldiamines are given in Table I. Those values found in our laboratory were obtained using 50 ml. pycnometers, using methods which have been described previously (5).

When water was considered the solvent and the apparent molal volume of the alkyldiamines calculated, the resulting plots were similar to those shown for ethylenediamine in Figure 3. No simple function

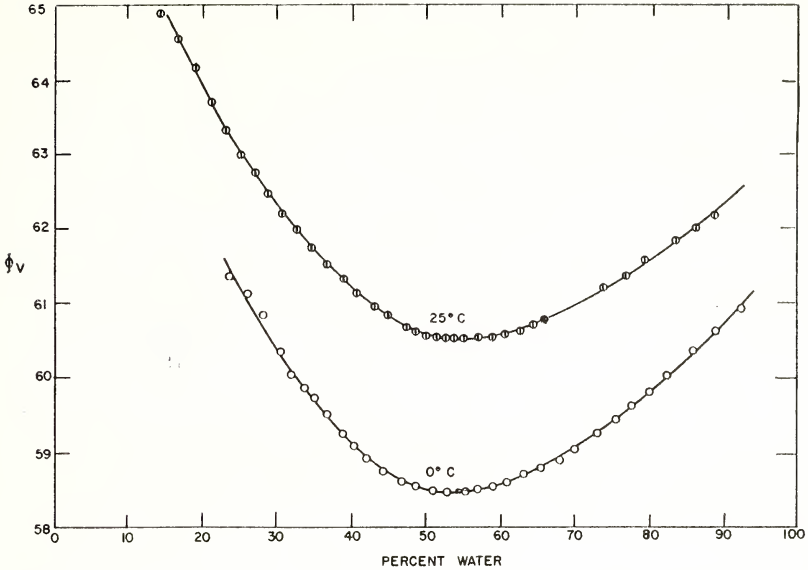

Figure 3. Apparent molal volume of ethylenediamine vs. weight percent water.

could be found to describe the curves, although all displayed the striking minimum which, within experimental error, corresponded to the maximum in the density isotherm for the corresponding system.

Earlier work in this laboratory (2,4) has shown that Masson's Rule (3) for apparent molal volumes holds for the ethylenediamine solvent system in the case of strong electrolytes. The rule can be expressed as,

$$\Phi_{V_2} = \Phi_{V_2}0 + K(m)^{1/2}$$

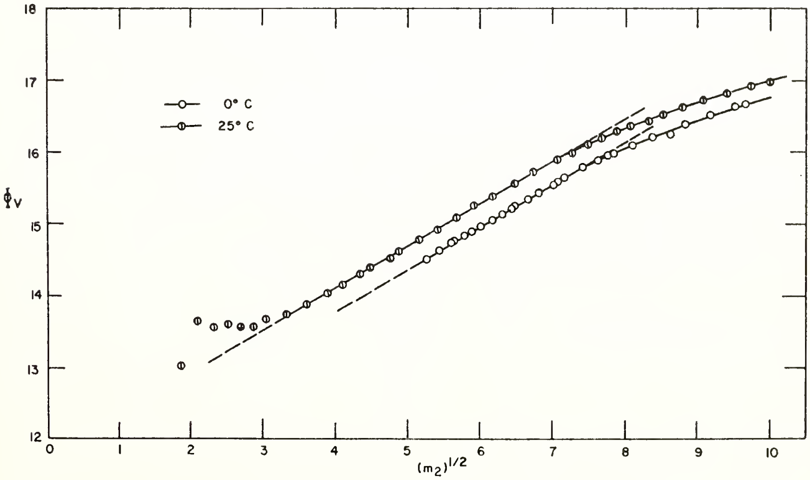

Figure 4. Apparent molal volume of water in ethylenediamine as a function of (m)½.

where $\Phi_{V_2}o$ is the partial molal volume at infinite dilution and K is the Masson constant.

Masson's work also indicated that deviations from this relationship occur at concentrations corresponding to a hydrate formation in many cases. Calculations of apparent molal volumes for water using the alkyldiamines as solvents give results which appear to obey Masson's rule. This is shown in Figure 4 for ethylenediamine.

In all cases the curves deviated from linearity at a concentration which corresponded to the maximum in the density isotherm.

A summary of the results for the three alklydiamines studied is given in Table 2.

From our results it appears that an ordered structure corresponding to a weak hydrate solvent shell may be occurring in solutions of alkyldiamines. This would account for the maximums in the density isotherms and their dependence on temperature. Further studies with NMR should indicate if a semi-stable hydrate is present and give an insight into its nature.

TABLE I
Densities of Pure Alkyldiamines

Alkyldiamine	Temperature	Density	Reference
ethylenediamine	0°C	0.91411	Timmermans (5)
	25°C	0.8922	this laboratory
	50°C	0.8793	Elgort (1)
methylethylenediamine	0°C	0.8845	by extrapolation
	25°C	0.8826	this laboratory
trimethylenediamine	0°C	0.8851	by extrapolation
	25°C	0.8597	this laboratory

TABLE II
Constants Derived from Density Data

Alkyldiamine	Temp.	ρ max.	Mole % Water at Maximum ρ	K	$\Phi_{V_2}o$
ethylenediamine	0°	1.01341	77.15	1.715	11.46
	25°	0.99533	80.52	1.717	11.78
	50°	(0.978)[1]	(83.7)	(1.73)	(12.0)
methylethylenediamine	0°	1.00763	82.66	1.32	10.3
	25°	(0.990)	89.73[2]	1.97	12.8
trimethylenediamine	0°	1.00632	85.13	1.68	10.8
	25°	(0.985)	92.31[2]	1.69	10.95

1. Values in parenthesis are uncertain.
2. Mole percent water corresponding to minimum in Φ_{V_2} curve for the alkyldiamine in water.

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A Spectral Comparison of 2-Quinolones with 2-Alkoxyquinolines

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Changes in structural features within a series of chemically related compounds can be correlated with changes in the electronic absorption spectra of these same compounds. This study involves the ultraviolet spectra-structure correlation for a series of 2-quinolones and 2-alkoxyquinolines.

Experimental

All spectra were determined at a constant temperature of 20°C. using a Bausch and Lomb Spectronic 505 recording spectrophotometer. The solvent was spectrally pure 95 per cent ethanol. The spectral range covered was from 205 to 350 millimicrons. The wave length reading of the instrument was calibrated using a mercury source; absorbance readings were checked at the various wave lengths using standard solutions of KNO_3 and K_2CrO_4.

Samples of each solid compound were purified by repeated recrystallization to a constant melting point range of 1° C. Liquids were fractionated to a constant boiling temperature. The melting points and the boiling temperatures agreed with literature values. Stock solutions of each compound were prepared by weighing followed by dilution with spectrally pure 95 per cent ethanol to a known volume. Aliquots of these stock solutions were further diluted with the solvent to a spectrophotometrically feasible concentration range. The ultraviolet spectrum of each compound was determined at several different concentrations. This technique checked instrument reproducibility as well as the validity of the Beer-Lambert Law for the molecule.

Results and Discussion

Table 1. summarizes the spectral features for the series of molecules studied. Region A describes the spectral features below 215 millimicrons, region B features between 215 to 240 millimicrons, region C features between 240 and 260 millimicrons, region D features between 260 and 300 millimicrons, and region E spectral characteristics above 300 millimicrons.

In this series of compounds the only ultraviolet spectrums that are reported in the recent literature are for 2-quinolone, 4-methyl-2-quinolone, and 1-methyl-2-quinolone. The results that are quoted for these molecules in Table 1. agree closely to those in the literature (1, 2, 3). The absorption maximum in the region of 210 millimicrons is previously unreported. As yet no attempt has been made to identify the different

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[1] This project was done as part of an Undergraduate Research Participation Program supported by the National Science Foundation at DePauw University during the summer of 1965.

TABLE 1

Spectral Characteristics of 2-Quinolones and 2-Alkoxy Quinolines in 95 Per Cent Ethanol

	Wave Length in mu. and Log e				
Compound	A	B	C	D	E
2-quinolone	210(4.43)	228(4.63)	245(3.83)s	268(3.85) 276(3.80)s	316(3.74)s 328(3.83) 340(3.63)s
4-methyl-2-quinolone	210(4.42)	230(4.59)	243(4.06)s	267(3.82) 276(3.78)s	315(3.77)s 325(3.86) 337(3.72)s
3-methyl-4-ethyl-2-quinolone	215(4.50)s	221(4.56)	246(3.92)s	264(3.79)s 270(3.88) 279(3.77)	315(3.82)s 325(3.90) 338(3.75)
3-ethyl-4-propyl-2-quinolone	217(4.42)s	222(4.53)	247(3.93)s	264(3.78)s 271(3.90) 281(3.82)	315(3.82)s 325(3.92) 340(3.77)
3-propyl-4-butyl-2-quinolone	215(4.42)s	225(4.50)	247(3.90)s	265(3.78)s 272(3.89) 281(3.80)	316(3.82)s 326(3.92) 340(3.84)
3-butyl-4-pentyl-2-quinolone	216(4.52)s	223(4.57)	245(4.02)s	264(4.02)s 272(3.95) 281(3.88)	316(3.86)s 326(3.97) 339(3.82)
4,8-dimethyl-2-quinolone		232(4.55)	247(4.23)	273(3.88) 281(3.84)s	318(3.68)s 329(3.76) 340(3.67)s
3-bromo-4-methyl-2-quinolone		230(4.48)	248(3.97)s	270(3.81)s 277(3.90) 287(3.83)	321(3.80)s 332(3.90) 346(3.76)
1-methyl-2-quinolone	212(4.39)s	229(4.59)	245(3.86)s	270(3.84) 278(3.82)	320(3.71)s 330(3.87) 340(3.67)s

TABLE 1 (continued)

Spectral Characteristics of 2-Quinolones and 2-Alkoxy Quinolines in 95 Per Cent Ethanol

Compound	Wave Length in mu. and Log e A	B	C	D	E
1,4-dimethyl-2-quinolone		230(4.60)	243(4.06)	269(3.89) 277(3.78)	318(3.74)s 327(3.80) 339(3.65)s
1,3-dimethyl-4-ethyl-2-quinolone		228(4.57)	246(3.96)s	266(3.76)s 273(3.88) 282(3.74)	317(3.80)s 326(3.84) 339(3.68)s
1-methyl-4-formyl-2-quinolone	213(4.46)s	229(4.55)	247(4.01)s	272(3.82) 279(3.78)	320(3.74)s 331(3.80) 343(3.65)s
2-methoxyquinoline	209(4.56)	225(4.56) 231(4.56)	256(3.81)	264(3.77)s 277(3.55)s 296(3.46)	304(3.51)s 308(3.55) 317(3.55) 321(3.51)
2-methoxy-4-methyl-quinoline	215(4.48)s	222(4.57)s 226(4.59)	248(3.59) 258(3.63)	267(3.63) 276(3.49)s 296(3.30)s	308(3.55) 322(3.59)
2-ethoxy-4,8-dimethyl-quinoline	209(4.62)	232(4.68) 238(4.47)		272(3.75) 284(3.57)s 300(3.32)s	311(3.51) 325(3.55)
2-methoxy-4,6,8-trimethyl-quinoline	212(4.63)	232(4.67) 238(4.67)		264(3.74) 273(3.72)	306(3.33)s 318(3.55) 332(3.58)

absorption bands with particular electronic transitions. However, it appears that the following spectra-structure correlations can be made:

1. 3,4-Disubstitution is characterized by its absorption features in regions D and E. In region D normal alkyl substitution in the 2-quinolone molecule shows a maximum-shoulder characteristic; 3,4-disubstitution shows a shoulder maximum-maximum feature. In region E the normal alkyl-substituted 2-quinolone spectrally shows a shoulder-maximum-shoulder feature; 3,4-disubstitution shows a shoulder-maximum-maximum feature. The replacement of an alkyl group by bromine in the 3-position produces the expected bathochromic shift but does not destroy the 3,4-disubstitution characteristic.

2. Alkyl substitution on the N atom spectrally shows a maximum-maximum feature in region D instead of a maximum-shoulder feature seen in the case of normal alkyl substitution.

3. 2-Alkoxyquinolines are characterized by a double maximum in region B instead of the single maximum characteristic of the 2-quinolones. In region E the ethers have a maximum-maximum feature at the longest two wave lengths instead of the shoulder-maximum-shoulder feature of the 2-quinolones.

The authors wish to thank Dr. D. J. Cook of DePauw University for making available samples of the various 2-quinolones and Dr. C. E. Kaslow of Indiana University for samples of the 2-alkoxyquinolines.

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O-Tolyl Biguanide Complexes of Some Transition Metal Ions in 1-Methyl-2-Pyrrolidinone

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The biguanides contain five nitrogen atoms and are remarkable coordinating agents. The general formula of a biguanide is $R_2NC(:NH)NHC(:NH)NR_2$, where R represents an alkyl, aryl, or hydrogen group. Only two of the five nitrogen atoms are involved when biguanides coordinate with metal ions to form complex ions. The complexes which form are chelates containing six-membered rings. Usually two or three biguanide molecules coordinate with each metal ion.

The ligand used in this study, o-tolyl biguanide, has the formula, $o\text{-}CH_3C_6H_4NHC(:NH)NHC(:NH)NH_2$. The compound is a bidentate ligand. The coordination chemistry of this ligand has not been extensively investigated, although the literature contains several references to certain other biguanides. Ray has prepared a comprehensive review listing most of the important papers concerning biguanide coordination chemistry published prior to 1961 (3). Some of the first biguanide complexes of cobalt and copper were prepared by Rathke in 1879 (2). However, the Co (II) compound was first isolated in the pure state by Ray and Ghosh in 1943 (4). In general, most of the quantitative studies of relatively pure biguanide complexes have been done since 1935. The present study was undertaken to find the dissociation constants and the molar absorptivities of four o-tolyl biguanide chelates.

Experimental

The solvent used in these studies was 1-methyl-2-pyrrolidinone purchased from Matheson, Coleman and Bell. O-tolyl biguanide is quite soluble in this solvent as are many inorganic salts. Further, the various complexes formed in this study were soluble in the solvent. Thus all the species used were soluble, and all the data reported below were obtained with solutions.

Most of the inorganic salts were used as the nitrates. Because of decomposition, these cannot be dried in ovens in the usual fashion. Instead, the hydrated salts were weighed and placed in 1-methyl-2-pyrrolidinone solutions and then dried with 2,2-dimethoxypropane. A ten percent excess of drying agent was added. The reaction is quantitative and proceeds as follows:

$$(CH_3)_2C(OCH_3)_2 + H_2O = CH_3C(:O)CH_3 + 2CH_3OH.$$

A Perkin-Elmer Model 202 recording UV-visible spectrophotometer was used to scan spectra of solutions containing only inorganic salts, solutions containing only o-tolyl biguanide, and solutions containing complexes of metal ions and o-tolyl biguanide. For precise absorbance determinations at selected wavelengths, a Beckman Model DU quartz spectrophotometer equipped with 1-cm. cuvettes was used. All data were collected at approximately 25°C.

Most of the solutions studied were quite stable. Some of the solutions did show a change in absorbance with time. When drifting was noticed, the absorbance data were taken with freshly prepared solutions.

The first system studied contained various amounts of $Co(NO_3)_2$ and o-tolyl biguanide. The data are listed in Table 1. The solution containing only $Co(NO_3)_2$ had a spectrum showing an absorbance peak at 525 mμ. This solution absorbed very little light at 400 mμ. The solution containing the complex showed characteristic absorption at 380 mμ. Therefore the latter wavelength was used to study the complex.

The second system involved complexes of $Cu(NO_3)_2$ and o-tolyl biguanide. The data are given in Table 2. The spectrum of a solution containing only $Cu(NO_3)_2$ showed a peak at 800 mμ and practically no absorbance at 500 mμ. The complex had a peak at 610 mμ. The optimum wavelength for the study was 540 mμ.

The third system was composed of $Ni(NO_3)_2$ and o-tolyl biguanide (see Table 3). The spectrum of a solution containing $Ni(NO_3)_2$ had one absorbance peak at 750 mμ and a second at 400 mμ. The spectrum of a solution of the complex had a maximum at 410 mμ. At wavelengths slightly greater than 400 mμ the absorbance of the Ni(II) fell much more rapidly than that of the complex solution. Therefore, 460 mμ was the wavelength which permitted the study of this system.

The fourth system contained $CrCl_3$ and o-tolyl biguanide. Solutions of $CrCl_3$ showed maxima at 500 mμ while solutions of complex showed maxima at 470 mμ. Below 450 mμ the absorbance of the Cr(III) dropped off rapidly. Thus, 390 mμ was deemed the best wavelength for the study of the complex.

Calculations and Results

Job's method of continuous variations was applied to the spectrophotometric data to determine the most stable complex in each case (1, 6). The absorbance data in Tables 1, 2, and 3 show that maxima occur at a ratio of one part metal ion to two parts ligand; therefore, the most stable complexes are of the form $M(\text{o-tolyl biguanide})_2^{++}$, where M represents Co(II), Cu(II), and Ni(II), respectively. The absorbance data in Table 4 indicate a maximum in the formation of a complex at a ratio of one part metal ion to 3 parts ligand; therefore, the most stable complex is $Cr(\text{o-tolyl biguanide})_3^{+++}$.

The data were analyzed to permit the calculation of the dissociation constant and the molar absorptivity of the most stable complex of each metal ion. A method of successive approximations as given in a previous paper was used in a modified form (5). The dissociation of a complex ion may be written as

$$MX_n = M + nX$$

and the dissociation constant as

$$K = \frac{[M]\,[X]^n}{[MX_n]} \tag{1}$$

Let ϵ_M = molar absorptivity of the metal ion, ϵ_X = molar absorptivity of the ligand, and ϵ_C = molar absorptivity of the most stable complex ion.

Then the total absorbance, A, for any solution containing metal ion and ligand is given by

$$A = \epsilon_M[M] + \epsilon_X[X] + \epsilon_C[MX_n] \tag{2}$$

assuming that the concentrations of intermediate complex ions are insignificant. In all the cases studied, solutions of the pure ligand absorbed light to no appreciable extent, thus ϵ_X was essentially zero and the second term was omitted from equation (2).

Using the symbol C_M to represent the total analytical concentration of metal ion added to the solution, and C_X to represent the total concentration of ligand, equation (2) can be written as

$$A = \epsilon_M (C_M - [MX_n]) + \epsilon_C[MX_n] \tag{3}$$

and equation (1) can be written as

$$K = \frac{(C_M - [MX_n])\,(C_X - n[MX_n])^n}{[MX_n]} \tag{4}$$

For solutions containing only metal salt, equation (2) becomes

$$A = \epsilon_M[M] \tag{5}$$

Thus the measurement of the absorbances of a series of solutions containing only metal ion permitted the calculation of ϵ_M.

The calculations were done by two methods. First, data were substituted directly into equation (5) and ϵ_M calculated. Secondly, graphs of [M] versus A were made and ϵ_M was determined from the slope of the line in each plot. This gave a check concerning the agreement of the absorbance data to Beer's law and gave statistical value to the determined ϵ_M. The values found were: $\epsilon_{Co} = 19.75$ at 380 mμ, $\epsilon_{Cu} = 1.30$ at 540 mμ, $\epsilon_{Ni} = 8.90$ at 460 mμ, and $\epsilon_{Cr} = 10.2$ at 390 mμ.

The data given in Tables 1-4 were used to calculate approximate values for ϵ_C. The data were plotted and an approximate ϵ_C was calculated for each of the systems by choosing a point where the metal ion concentration was very low and the ligand concentration was relatively high. Under such conditions, the concentration of the metal ion in solution is practically zero and the concentration of the complex ion, MX_n, is nearly equal to the analytical concentration of the metal ion; that is, nearly all the solvated metal ion is converted to complex ion. Thus, as an approximation, equation (3) becomes $A = \epsilon_C[MX_n]$ or $A = \epsilon_C C_M$ and an approximate ϵ_C could be calculated.

The calculation was continued by using the absorbance data at the maximum of each curve, that is, at the point where the complex was formed most strongly in each case. The known values for A, ϵ_M, C_M, and the approximate value for ϵ_C were substituted into equation (3), permitting calculations of the approximate concentrations of the complex ions. The data were then substituted into equation (4) to allow the calculation of an approximate dissociation constant.

The data at the first point, that is, at low C_M and high C_X, were substituted into equation (4) and by using the approximate K previously determined at the maximum point, the concentration of the complex ion could be determined. In all cases, this was lower than the value used in the first approximation since a small portion of the solvated metal ion was not converted to the complex ion. Thus a better approximation for the concentration of the complex ion was now available, and this value was substituted into equation (3) to permit the calculation of a better value for ϵ_C. This value for ϵ_C was used again at the second point, the maximum on the curve, to obtain a better value for the concentration of the complex using equation (3). Then a better value for K was calculated at point 2 and this value used again at point 1 in the same fashion as discussed above. These calculations were repeated for each system until no change was noted in ϵ_C or K, indicating that the approximate values had converged to the actual values. Usually three or four cycles of calculations were required.

The final calculated values for $Co(C_6H_{14}N_5)_2{}^{++}$ were $K = 1.14 \times 10^{-11}$ and $\epsilon_C = 642$ at 380 mμ. Those for $Cu(C_6H_{14}N_5)_2{}^{++}$ were $K = 1.98 \times 10^{-7}$ and $\epsilon_C = 72.6$ at 540 mμ. The results for $Ni(C_6H_{14}N_5)_2{}^{++}$ were $K = 1.60 \times 10^{-7}$ and $\epsilon_C = 88.1$ at 460 mμ. For $Cr(C_6H_{14}N_5)_2{}^{+++}$ the corresponding values were $K = 4.21 \times 10^{-11}$ and $\epsilon_C = 708$ at 390 mμ.

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TABLE 1

Conc. Co(II) ($X\ 10^3$ M)	Conc. o-tolyl big. ($X\ 10^3$ M)	Absorbance at 380 mμ
4.00	0.00	0.079
2.80	1.20	0.178
2.40	1.60	0.343
2.00	2.00	0.514
1.80	2.20	0.645
1.60	2.40	0.672
1.40	2.60	0.833
1.20	2.80	0.768
0.80	3.20	0.368
0.00	4.00	0.000

TABLE 2

Conc. Cu(II) (X 10^2 M)	Conc. o-tolyl big. (X 10^2 M)	Absorbance at 540 mμ
2.00	0.00	0.026
1.40	0.60	0.143
1.20	0.80	0.200
1.00	1.00	0.264
0.90	1.10	0.303
0.80	1.20	0.369
0.70	1.30	0.428
0.60	1.40	0.424
0.50	1.50	0.355
0.40	1.60	0.260
0.00	2.00	0.003

TABLE 3

Conc. Ni(II) (X 10^2 M)	Conc. o-tolyl big. (X 10^2 M)	Absorbance at 460 mμ
2.00	0.00	0.178
1.40	0.60	0.319
1.20	0.80	0.374
1.00	1.00	0.428
0.80	1.20	0.489
0.70	1.30	0.538
0.60	1.40	0.492
0.50	1.50	0.438
0.40	1.60	0.343
0.30	1.70	0.254
0.00	2.00	0.002

TABLE 4

Conc. Cr(III) (X 10^2 M)	Conc. o-tolyl big. (X 10^2 M)	Absorbance at 390 mμ
1.00	0.00	0.102
0.70	0.30	0.115
0.60	0.40	0.123
0.50	0.50	0.128
0.45	0.55	0.140
0.40	0.60	0.200
0.35	0.65	0.481
0.30	0.70	0.908
0.25	0.75	1.600
0.20	0.80	1.610
0.10	0.90	0.925
0.05	0.95	0.354
0.00	1.00	0.001

The Standard Free Energy of Formation of Magnesium Bromide From Its Elements

JOHN A. RICKETTS and PAUL BROWN, DePauw University

The ionic nature of diethyl ether, Et_2O, solutions of magnesium bromide is well known. Gillet (6) obtained a cathode deposit of elemental magnesium from a $MgBr_2$-Et_2O solution; Evans (5) and Dessy (3) have investigated the electrochemical transport properties of this system. No reversible electrode potential for the magnesium ion in any solvent has been experimentally measured. The value of +2.378 volts was calculated by Coates (2) using thermochemical data coupled with solubility data for $Mg(OH)_2$. This study investigates the galvanic behavior of the electrochemical cells, Mg/ $MgBr_2.2Et_2O$ (s) in Et_2O/ AgBr/ Ag and Hg-Mg (1)/ $MgBr_2.2Et_2O$ in Et_2O/ AgBr/ Ag.

Experimental

All electromotive force measurements were made at a constant temperature of 15.20 ± 0.05° C. using a Leeds and Northrup potentiometer, type K-2. Throughout any series of measurements the system was constantly purged with helium. In unpurged systems erratic behavior of the e.m.f. was noted; the stable potentials realized in purged systems quickly dropped to 0.9 volts when either air or oxygen was admitted into the system.

The electrode materials were the purest obtainable. The Ag/ AgBr electrodes were prepared electrochemically according to the procedure of Brown (1). The reproducibility of the Ag/ AgBr electrodes was checked frequently. In the galvanic couple, Ag/ AgBr/ HBr (0.01 M.)/ AgBr/ Ag, the potential differences between electrodes never exceeded 0.00002 volts; for the cell, Ag/ AgBr/ $MgBr_2$ in Et_2O/ AgBr/ Ag, the potential differences between electrodes were always less than 0.001 volts.

Magnesium electrodes were prepared from sublimed magnesium rod (spectrographic analysis—Ca, Si, and Sn less than 0.01 per cent; Al, Cu, Fe, Mn, Pb, and Zn less than 0.001 per cent; Ni less than 0.0005 per cent). Machined magnesium slugs of ½ inch diameter were sealed into pyrex tubing with an epoxy resin. At least a one centimeter length of magnesium rod remained exposed for contact with the solution. External contact to the electrodes was made by a platinum wire dipping into a mercury pool in contact with the magnesium slug. Preliminary to each run, the electrodes were cleaned using the Dow acetic-nitrate pickling bath (7), thoroughly rinsed with anhydrous Et_2O, and quickly transferred into the $MgBr_2$-Et_2O electrolyte. The magnesium amalgam electrodes were prepared by weighing the proper quantities of magnesium and mercury into the cell used to hold the electrolyte; all weighings were done under a helium atmosphere.

The solid $MgBr_2.2Et_2O$ was prepared using chemically pure or reagent grade materials by the method described by Evans (4). In all measurements the electrolyte was a saturated solution of

$MgBr_2.2Et_2O$ in Et_2O. During all determinations solvent lost through evaporation was replaced by adding electrolyte.

Results and Discussion

TABLE 1

Electromotive Force Values for the Cell, Mg/ $MgBr_2.2Et_2O$ (s) in Et_2O/ AgBr/ Ag.

	Run	
Electrode	1	2
I	1.425 ± 0.010 v. (5 hr.)	1.422 ± 0.001 v. (1 hr.)
II	1.427 ± 0.002 v. (1 hr.)	1.421 ± 0.002 v. (2 hr.)
III	1.417 ± 0.005 v. (3 hr.)	electrode broken
IV	1.416 ± 0.002 v. (2 hr.)	1.412 ± 0.015 v. (3 hr.)

Table 1 summarizes the e.m.f. measurements for the electrochemical cell, Mg/ $MgBr_2.2Et_2O$ (s) in Et_2O/ AgBr/Ag. Stable values were only realized after the electrodes had been in contact with the electrolyte for from 10 to 20 hours. The tabulated values are average values observed during the time period listed in parentheses below the individual electrode. The deviation quoted is the maximum deviation of any measured value from the average. Statistically the most reliable estimate for the e.m.f. of this galvanic cell is 1.420 ± 0.008 volts at 15.20°C. Figure 1 summarizes the results obtained for the amalgam electrodes as a function of the mole fraction of magnesium in the amalgam. The experimental results are best represented by the equation,

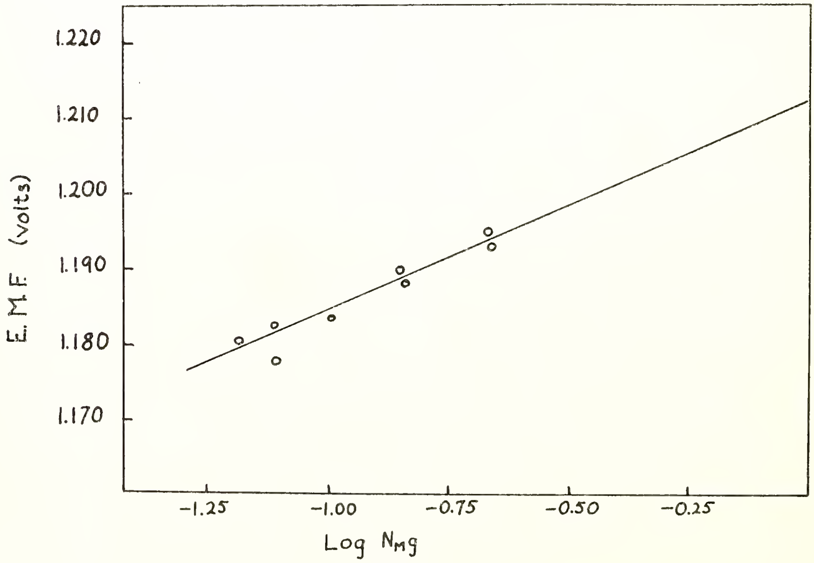

Figure 1

$E = 1.213 + 0.0292 \log N_{Mg}$.

The predicted slope for a two electron, reversible process is 0.0286 volts at 15.20° C. The agreement between experiment and theory strongly suggests that the Ag/ AgBr reference electrode behaves reversibly in the $MgBr_2$-Et_2O electrolyte.

From the value of 1.420 volts the free energy change for the chemical reaction at 15.20° C.,

$$Mg\ (s) + 2\ AgBr\ (s) + 2\ Et_2O\ (1, \text{satd. soln.}) \rightarrow MgBr_2.2Et_2O\ (s) + 2\ Ag\ (s)$$

is —65.50 kcal. mole $^{-1}$. Evans (4) has determined the Et_2O vapor pressures of the various $MgBr_2$-Et_2O systems as a function of the absolute temperature. From these results the free energy change for the reaction,

$$Mg\ (s) + 2\ AgBr\ (s) \rightarrow MgBr_2\ (s) + 2\ Ag\ (s)$$

is calculated to be —63.97 kcal. mole^{-1}.

The standard free energy of formation of $MgBr_2$ is defined as the free energy change associated with the formation of this compound from its elements at 25° C. By means of the Gibbs-Helmholtz equation and the appropriate free energies of formation, enthalpies of formation, and molar heat capacities for Br_2, Ag, AgBr, Mg, and $MgBr_2$ as listed in the National Bureau of Standards tabulation of thermochemical quantities (8), a value of -109.92 ± 0.75 kcal. mole^{-1} is obtained for the standard free energy of formation of $MgBr_2$. It should be pointed out that the molar heat capacity of $MgBr_2$ is not experimentally available; the estimated value of 19.8 cal. deg.$^{-1}$ mole^{-1} has been used in the calculation (9).

The authors wish to thank Mr. Brian Wicke for his statistical treatment of the vapor pressure data for the $MgBr_2$-Et_2O systems in order to obtain the necessary values for the calculation.

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ENTOMOLOGY

Chairman: GERTRUDE L. WARD, Earlham College
RAY T. EVERLY, Purdue University, was elected chairman for 1966

ABSTRACTS

Reproductive Behavior of the Damselfly, ***Hetaerina americana*** **(Fabricius) (Odonata: Calopterygidae).** GEORGE H. BICK and DIANE SULZBACH, Saint Mary's College.—Field observations in southern Oklahoma during June and July showed scarcely any daily or hourly fluctuation in numbers at water. Males probably spent the night at water and unpaired females were routinely present. Territorial activity among females was indicated. There was no courtship or display of any kind by either sex. Males, inattentive to motionless females approached them when they flew. Sperm transfer followed each seizure, was always in tandem, and averaged 7 seconds. Copulation, lasting 3 minutes, quickly followed at water. Pairs then flew briefly in tandem, separated without distinctive behavior, and the female descended to oviposit alone in willow roots for an average of 27 minutes. During this obligatory submerged oviposition, each female remained near the site of descent and her mate perched nearby exhibiting guarding behavior by flying toward and displacing conspecific male intruders.

Occurrence of ***Culiseta minnesotae*** **Barr in Indiana.** R. E. SIVERLY, Ball State University.—One larva of *Culiseta minnesotae* Barr was collected in a small bog in LaGrange County, Indiana, in early May, 1965. No adults were collected. The larva was reared in the laboratory and emergence occurred approximately one week after the larva was collected in the field. Identification of the emerged adult specimen was confirmed by Dr. Alan Stone of the U. S. National Museum.

Little is known concerning the biology of *C. minnesotae*, and its occurrence in Indiana is believed to be infrequent or rare. So far as it is known, there is no previously published account of the occurrence of this mosquito in Indiana.

Population buildup of corn leaf aphid, ***Rhopalosiphum maidis*** **(Fitch), on corn in Floyd County, Indiana.** E. S. SAUGSTAD, Purdue University.—The corn leaf aphid, *Rhopalosiphum maidis* (Fitch), has been proven a vector of Maize Dwarf Mosaic (MDM) in the laboratory. As it has a wide host range including some species of grasses that may serve as overwintering hosts of the MDM virus, this aphid is strongly suspected to be a field vector. MDM has recently invaded southern Indiana along the Ohio River, where Johnson Grass, *Sorghum halepense* (L.), is prevalent. One of the purposes of this study was to observe population trends of the corn leaf aphid on corn and grasses in Floyd County, Indiana. Preliminary results indicate that these aphids arrive in the area before corn is out of the ground and infest Johnson Grass. Aphids are found on corn shortly after plant emergence, increasing in number slowly until the corn is about four to five weeks old. From this time up until tasselling, the percentage of infested plants increases rapidly. The number of aphids per infested plant remained relatively low until shortly before the corn tasselled. Alate aphids on corn other than those originally infesting the plants were not observed until densities of up to 1000 aphids per plant occurred.

Corn Leaf Aphid Resistance in Dent Corn. RAY T. EVERLY, Purdue University.—For the past six years, corn leaf aphid infestation has reduced corn yields in Indiana an average of 18,000,000 bushels annually. Insecticides give excellent control but it is extremely difficult to determine their need and timing. Corn resistance and tolerance to aphid establishment has been observed and offers the best means of limiting losses from the insect.

Plants of inbreds and single crosses in replicated tests at Evansville, Indiana were observed at tassel emergence for the degree of aphid infestation. Among the inbreds, W22 had the fewest plants infested with none moderately or severely attacked. Ky 27 had 100% infestation and 81.9% of these were moderately and severely infested. Oh 51A had 62% infested and 3.8% were in the moderate-severe class, whereas 38-11 had only 47.6% infestation but 6.9% were moderately-severely infested. Similar results were observed among the single crosses. In general, total infestation is not the best criterion for judging the resistance and tolerance of dent corn to aphid attack.

Although low-infested inbreds tended to produce low-infested single crosses and high-infested inbreds single crosses with high infestation, there were numerous exceptions indicating a possible highly complex genetic pattern. Maturity was found to be an important factor in degree of infestation.

Radiosensitivity of the Yellow-Fever Mosquito, *Aedes aegypti*. SISTER MONICA ASMAN and K. S. RAI, University of Notre Dame.—The effects of different doses (500-64,000r.) of gamma rays on egg hatchability, rate of growth and development, viability to adulthood, longevity, and reproductive capacity were studied on the Rock strain of *Aedes aegypti*. Different stages of development in the mosquito life cycle were irradiated for this purpose. Hatching percentages following egg irradiation were not affected by 500 r. However, beyond this dose, percent hatch decreased directly as the dosage was increased. Even at 64,000 r., 5% of the treated eggs hatched, although none of them lived beyond the fourth day. Larvae irradiated at 1000r. and up, and in the first, second, or third instar were inhibited from reaching the adult stage; only eggs and the fourth instar were able to complete development when exposed up to 2000 r. The rates of development, measured by metamorphosis and the count of dividing cells in the brain, decreased as dosage was increased. An increase of dosage also resulted in reduced longevity. Measured in terms of any of the above-measured criteria, the second-instar larvae were most sensitive to irradiation. On the cytological level, chromosomal aberrations in the form of reciprocal translocations, inversions, and polyploidy were found in the irradiated material. Heterosis proved to be a protective factor against radiation damage.

Behavior of the Damselfly, *Lestes unguiculatus* Hagen (Odonata: Lestidae).

George H. Bick and Lothar E. Hornuff, Saint Mary's College,
Notre Dame, Indiana, and Central State College,
Edmond, Oklahoma.

This work, part of a general study[1] of reproductive behavior in the suborder Zygoptera, adds the genus *Lestes* to our studies on *Enallagma* (2), *Argia* (3), and *Hetaerina* (5), affording a broader ethological basis for phylogenetic considerations. The following notes describe behavior of unpaired males and reproductive behavior in *Lestes unguiculatus* Hagen, a member of the Lestinoidea, a group considered (9) primitive on non-ethological evidence.

Observations were all in the field during June and July in St. Joseph County, Indiana, at a 135 x 144′, 1-3′ deep bog pond supporting abundant emergent vegetation, primarily *Sagittaria latifolia*, *S. rigida*, and *Sparganium androcladum.* Methods and terminology are essentially as in our studies of *Argia* and *Enallagma.* The primary aim was to describe and time behavior of unpaired males and pairs by constantly observing distinctively marked individuals.

Behavior of Unpaired Males

Hourly counts of marked individuals on five days showed that males were most abundant from 1300 to 1600 hours. Between these hours on various days, we constantly observed and recorded all activity of each of 12 marked males for a 20-minute interval. The 554 events tallied during the 240-minute total provided scarcely any evidence of territorial behavior.

The most frequent event was a shift of perch site for no detectable reason, averaging 21 per individual (Table 1) or approximately one shift each minute. When a male reached a perch, he occupied it only momentarily; when he shifted, it was usually for more than 3 feet, so that during one 20-minute episode a male usually moved around an entire margin of the pond. This frequent shifting gave the impression of consistent and random cruising among or just above the vegetation. In contrast, *Argia apicalis* (3), a species which successfully defended territory, seldom shifted perch, but frequently, and for no detectable reason, darted out from and quickly returned to the same perch in a maneuver considered effective in maintaining territory.

When other Zygoptera approached, *unguiculatus* males seldom (Table 1) reacted, and as a result were displaced an average of once every 2 minutes. *Enallagma* males, and even the very small *Ischnura verticalis*, not only approached and displaced *unguiculatus*, but also often aggressively pursued them in flight. On the other hand, an aggressive species such as *apicalis* (3), always reacted to other Zygoptera and was seldom

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[1] Supported in part by research grant GM-10155 from the National Institutes of Health, U.S. Public Health Service.

TABLE 1
Total activity of 12 different unpaired males, each observed constantly for a 20-minute interval.

Activity	Number of events	Average per individual	Per cent won
No reaction, displacement	163	13.6	24
Wing-warning	54	4.5	89
Flight toward	49	4.1	33
Contact	3	0.2	0
			39
Shift, no reason	252	21.0	—
Feeding flights	8	0.7	—
Flight, no reason	13	1.7	—
Grooming	12	1.0	—
	554	46.1	

displaced. Although *unguiculatus* males wing-warned (2) and flew toward intruders, these events were infrequent and unsuccessful with one exception. Males of *unguiculatus* "won" (2) only 39% (Table 1) of all encounters, *apicalis* 87% (3). Because of this striking lack of aggressive behavior, *unguiculatus* males failed to maintain territory, even a single stem.

Loibl (11) states that *Lestes* males flew toward and attempted tandem with any passing Zygoptera. Quite differently, *unguiculatus* usually retreated when any Zygoptera approached. On the few occasions when *unguiculatus* males advanced toward other males, we never noted attempted intra or interspecific tandem.

Reproduction

Between 1330 and 1500, the hours of maximum reproductive activity, we studied 29 pairs. Eleven (Table 2) were observed constantly and timed during at least one reproductive phase, and one of these pairs was followed constantly throughout all phases.

Because the already abundant males immediately seized arriving females, unpaired females were rare at water. So, attempting to observe seizure and then to follow the entire reproductive process, we gave careful attention to the only unpaired female encountered during the season which had not mated earlier in the day. For 17 minutes she perched motionless on *Sparganium* over water. Suddenly, without signals or display of any kind, a male flew to her and instantly achieved tandem. There was clearly no courtship, display, or signals by either member. Experiments with models further demonstrated that activity of the female was not required to bring the sexes together. In 17 different trials, each of 12 males flew directly to and made tandem with a dead female, pinned to a stick and held motionless before him.

Courtship and territorial behavior have been considered (6, 8, 10) characteristic of recent groups. If correct, *unguilatus* appears to be primitive, because territorial activity was very poorly developed and courtship entirely absent in our population. Moreover, the present observations, combined with those on *Lestes disjunctus australis* (1), suggest on ethological evidence a primitive position for the entire genus.

Sperm transfer was always in tandem, as in some other Lestidae (4, 11), and probably in the entire suborder (4). In *unguiculatus*, the event, averaging 29 seconds, was over water or damp mud, between 1307 and 1530, as pairs perched 5-18 inches high on *Sparganium* or *Sagittaria*. Attempts to copulate followed immediately after each sperm transfer at the same perch.

Copulation was never a continuous process; each pair momentarily broke contact at intervals. Once, for example, contact lasted 3, 8, 4, 1, 4, and 7 minutes. Exclusive of the momentary interruptions, copulation averaged 25 minutes (Table 2). Nielsen (in 8) reports only 6 minutes in copula for *Lestes barbarus*, but we believe this was only one phase of an interrupted sequence. Loibl (11) gives 21-36 minutes of copulatory contact for *L. viridis*, 26-47 for *sponsa*, and 47-75 for *dryas*.

TABLE 2

Duration of reproductive activity in 11 pairs. For the first, timing was continuous for all events; for the others timing was complete for one or more events, incomplete (inc.) or missing (—) for other events.

Sperm Transfer (seconds)	Copulation (minutes)	Exploration in tandem (minutes)	Oviposition	
			tandem (minutes)	alone (minutes)
21	27	25	117	none
—	inc.	21	116	17
—	inc.	42	89	none
—	inc.	26	90	none
34	23	inc.		
—	24	inc.		
—	26	inc.		
21	inc.			
25	inc.			
34	inc.			
38	inc.			
21-38	23-27	21-42	75-117	
28.8	25.0	28.5	99.0	

Seven pairs copulated over water or damp mud while perched on *Sparganium*, whereas four were 10-25 feet from water on terrestrial weeds. Regardless of initial site, pairs usually shifted during this period, breaking copulatory contact as they moved. During copulation, the male abdomen pumped slowly (12/minute) and intermittently, the female's legs clasped her abdomen, and the male's metathoracic legs often contacted (3) the female abdomen in a kicking motion just prior to termination.

Immediately after copulation, pairs shifted frequently from one leaf or stem to another, one pair 106 times in 42 minutes. Since the female probed each stem very briefly, we believe that few eggs were deposited at this time and designate this activity, which averaged 28 minutes (Table 2), as exploratory. After exploration, pairs seldom shifted and settled at some small area for an average of 99 minutes of oviposition in tandem.

Unlike *Ischnura verticalis*, *Enallagma aspersum*, *E. civile*, and *E. ebrium*, which at this pond oviposited at or below the water surface, 10 of 13 *unguiculatus* pairs laid eggs in vegetation over damp mud or dry soil, usually 7-12″ above the surface. Even though two pairs laid eggs over water, and one completely submerged for 30 seconds, all oviposition sites became dry as the season advanced and the water level receded.

Sparganium stems near the white flowering heads were utilized for 78% of the total oviposition time; three pairs (Table 2) oviposited here constantly for 90, 116, and 117 minutes; and six of nine pairs observed for a part of oviposition used this material. *Sparganium* flower stems seemed to have been selected because *Sagittaria* and leaves of *Sparganium* were abundant but were never utilized. Pairs often shifted rapidly among such vegetation, yet when they perched near the white flowering heads of *Sparganium* the female quickly began prolonged oviposition.

Our pairs were widely spaced around the pond, never close together at the same stem as Walker (13) reports for *unguiculatus*, or clumped at a few communal sites as we (3) record for *Argia apicalis*. The abundance of *Sparganium* relative to the size of our population obviated the necessity for crowding at the oviposition sites. Crowding is apparently not species specific, but characteristic of the particular ecological sitution.

When ovipositing pairs perched near the surface among dense vegetation, other Zygoptera seldom disturbed them, and some pairs spent long periods without defense activity of any kind. However, most maintained a stem when intruders did approach. A 207-minute record of all activity of two pairs showed that both held a stem almost entirely by wing-warning. In spite of the warnings, each of five males momentarily grasped an ovipositing female without achieving tandem or displacing the mate.

During oviposition, both sexes were always vertical in the typical (7) *Lestes* position. The female, constantly in the egg laying position, moved very slowly backwards down the stem pulling the male along as she advanced.

One female laid a complete clutch of 116 eggs in a very slender terrestrial grass stem during 89 minutes of uninterrupted oviposition. Another female laid 173 eggs in a *Sparganium* flowering stem during 68 minutes, but this was not a complete clutch since we were unable to count the eggs subsequently deposited in a brief interval at another stem.

The slower rate of deposition in the grass (1.3/minute) than in *Sparganium* (2.8/minute) seems due to the more abundant vascular and supporting tissue in the grass.

Unlike Robert's (12) figures of other *Lestes* species, egg scars of *unguiculatus* were not elevated above the plant epidermis and were very close together, appearing to the unaided eye as a continuous straight line. A black, scarcely elevated flap of cells covered each egg, lying at an angle of 45 degrees, about 1 mm beneath the surface, and with its more pointed pole outermost.

We noted a male *Lestes rectangularis* in tandem with a marked female *unguiculatus* without seeing sperm transfer or copulation, but the female was in the egg laying position for 3 minutes. The male "bit" (2) the female twice, whereupon the pair flew off and was lost for 25 minutes. We then located and collected the pair, still in tandem and the female still in the egg laying position. Mixed pairs are not unusual among European *Lestes*; Loibl (11) records many, both in the field and in laboratory cages.

Summary

Behavior of distinctively marked unpaired males and pairs were studied under field conditions. Territorial behavior was poorly developed and courtship entirely absent, giving ethological support to the primitive position of the Lestinoidea. Sperm transfer averaged 29 seconds, copulation 25 minutes, exploration 28 minutes, and effective oviposition 99 minutes. Sperm transfer was in tandem, with copulation immediately following at the same site; thereafter pairs shifted widely, eventually settling for prolonged egg laying at one site which was usually a stem of *Sparganium* near a white flowering head. The complete clutch of eggs for one female was 116 in 89 minutes of uninterrupted oviposition.

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Insects and Other Arthropods of Economic Importance in Indiana During 1965

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The bioclimate during the growing season of 1965 was such that two distinct groups of insects were favored at different times. From May until mid-July, dry conditions prevailed and pests such as chinch bugs, potato leafhoppers, armyworms and flea beetles were of economic importance. The period from late July through September was cooler and wetter than normal and insects such as vinegar flies (*Drosophila* spp.) and stable flies increased to economic, and in the case of the stable fly, very annoying levels.

Temperatures were generally cooler than normal in Indiana from January through August of 1965 ("normal" being the 30 year average from 1931 through 1960). May was the only month that was warmer than normal, and temperatures averaged 4.6° F to 6.4° F higher than usual throughout the state.

Precipitation fluctuated a great deal more throughout the state than the temperature did during 1965. Precipitation was generally normal to above normal during January, February, April, July, August and September. Areas of Indiana receiving less precipitation in the above months were the southern one-third during January, and the east central sector and northern one-third during July. Sub-normal precipitation occurred throughout Indiana during March, May and June.

The month of May was particularly interesting in that it combined temperatures of 4.6° to 6.4° F above normal with precipitation that was 0.89 inches below normal in north central Indiana and from 1.27 to 2.71 inches below normal throughout the rest of the state. This combination of high temperatures and low precipitation made for rapid moisture loss which was reflected in the build up of "dry year" insects.

Cereal, Forage and Vegetable Insects

Alfalfa plant bug (*Adelphocoris lineolatus* (Goeze)) populations were unusually abundant in alfalfa throughout the 1965 growing season in Indiana. Mixed populations of nymphs and adults reached densities ranging from 8 to 18 per sweep in the southern one-half of the state during the last two weeks of May. On July 9, densities reached 4-12 per sweep, and on July 30, densities averaged 5-7 per sweep in the southern areas of the state. In the northern areas of the state, alfalfa plant bug populations were not as heavy as in the south and peak densities of 3 to 10 per sweep were reached during the last two weeks of July.

Alfalfa weevil (*Hypera postica* (Gyll.)) populations reached economic densities for the first time since it was discovered in Indiana in 1964.

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[1] Information for this summary has been provided by: J. A. Clark, M. L. Cleveland, R. C. Dobson, R. T. Everly, J. J. Favinger, R. L. Giese, G. E. Gould, G. E. Lehker, D. L. Matthew, J. D. Paschke, D. P. Sanders, D. L. Schuder, M. C. Wilson.

The alfalfa weevil extended its range to include twenty-six new counties during 1965 (Posey, Pike, Daviess, Sullivan, Greene, Clay, Owen, Martin, Crawford, Orange, Lawrence, Morgan, Johnson, Bartholomew, Jackson, Washington, Floyd, Clark, Scott, Jennings, Decatur, Shelby, Rush, Franklin, Ripley and Dearborn). Of these twenty-six counties, only Floyd County had economic infestations. Indiana now has a total of thirty-six counties in which the alfalfa weevil is present. It is interesting to note that in 1964 the alfalfa weevil in no case exceeded one adult or larval specimen per 500 sweeps with a 15 inch net. Population densities in 1965 were much higher (1 to 10 per 100 sweeps) in the twenty-six newly infested counties. In 1964 it was anticipated that moderate to severe damage to first growth alfalfa would occur in 1966 in those counties adjacent to the Ohio River. This prediction was based upon data other states (Ohio, Maryland, West Virginia, etc.) had obtained. Since the alfalfa weevil reached economic densities in areas of Harrison and Floyd Counties and approached economic levels in Posey, Gibson, Washington and Clark Counties in 1965, it would appear that this pest is becoming established in extreme southern Indiana more rapidly than expected. The alternative explanation is that the alfalfa weevil invaded Indiana prior to 1964 and is developing similar to the way it has in other states.

Armyworm (*Pseudaletia unipuncta* (Haw.)) infestations caused considerable damage to small grains in southern Indiana during May and early June. Larval populations as high as 2/sq. ft. were found in wheat and barley in areas of Washington, Dubois, Gibson and Knox Counties. Scattered economic infestations were also present in seedling corn throughout the above areas during May and early June. In the northern one-third of the state, scattered reports of damaging armyworm infestations in small grains were received during the latter half of June.

A billbug (*Sphenophorus* sp.) No reports of economic damage were received concerning this insect. It was apparently at the lowest population levels in the last three years.

Black cutworm (*Agrotis ipsilon* (Hufnagel)) populations reached economic levels in localized areas throughout central Indiana during the first two weeks of June, 1965. The largest single infestation occurred in Tippecanoe County where one, forty acre corn field had to be replanted and an adjacent one hundred acres of corn treated with insecticide. In general, infestations were more widely distributed in central Indiana during 1965 than they have been for the past few years.

Blister beetle (*Epicauta* spp.) adults were common in alfalfa during the middle of June, but were of no economic importance.

Cabbage maggot (*Hylema brassicae* (Bouché)) infestations caused serious losses to radishes and turnips in commercial plantings in Howard County during June of 1965. A 25 percent loss in a commercial planting of early cabbage was also reported from Howard County.

The cereal leaf beetle (*Oulema melanopus* (L.)) extended its range in Indiana to Benton, Warren, Tippecanoe, Hancock, Henry, Wayne, Delaware, Clinton and Randolph Counties in 1965. However, the New Carlisle area of St. Joseph and LaPorte Counties remained the only site where heavy populations were present. This was also the case in 1964. Activity of overwintering adults was delayed approximately two weeks in 1965 when compared with the previous two years. No activity was observed until April 16, 1965. The first egg of the season was found on April 30 on wheat at New Carlisle. Heavy movement of adults from wheat to oats occurred in LaPorte and St. Joseph counties during the week of May 9-15. Peak egg hatch on wheat occurred May 21-23, and in oats, peak hatch occurred June 7-10. Larval populations averaged as high as 3 to 4 per stem in some oat fields around New Carlisle during mid June. Pupation in oats reached the 90% point around May 25 in LaPorte and St. Joseph counties, and peak adult emergence had occurred by July 16. By July 23, 75-80% of the summer adults from oats had gone into aestivation, and all activity had ceased by August 6, 1965.

Two new cereal leaf beetle parasites were released at three sites in the New Carlisle area during 1965. The two parasites, *Tersilocus* sp. and *Hyposoter* sp. were introduced from southern Europe. A total of three parasites of the cereal leaf beetle have now been introduced into northern Indiana.

Chinch bug (*Blissus leucopterus* (Say)) populations reached economic proportions for the first time in three years in northwestern Indiana during 1964. From June 20 through July 16, 1965, heavy chinch bug infestations in corn and wheat (mostly corn) occurred in Jay, Blackford, Delaware, Wells, Adams, Allen and Wabash counties in eastern Indiana and in Lake, Newton, Jasper, Benton and Warren counties in western Indiana. The infestations in the western counties were individually more severe than those in the eastern counties, but the infestations in the eastern areas were more extensive. The chinch bug outbreak in the east central area of Indiana was reported to be the most severe in fifteen years.

Precipitation data from east central Indiana for May, June and July of 1965 shows a deficit of 2.17, 2.74, and 1.17 inches respectively. In the northwest sector of the state precipitation was 1.42 inches below normal during May and 2.35 inches below normal in June. Coupled with the dry conditions that were present in east central and northwestern Indiana were temperatures of 6.4°F above normal during May in the east central area, and 5.6°F above normal in the northwestern area. From the above data it is apparent that chinch bug conditions were optimum for an outbreak during the spring and early summer of 1965.

The clover root curculio (*Sitona hispidula* (Fabr.)) has not been included in this report for a number of years, but the abundance of this insect in alfalfa throughout Indiana during 1965 warrants mentioning at this time.

Adults were extremely abundant in litter of alfalfa fields in Floyd and Harrison counties during mid June. In early September adults averaged two per sweep in alfalfa throughout the northern one-third of the state. The larvae feed on the roots of alfalfa and clover, so the damage caused by this insect is difficult to assess. This is especially true since the major symptom of clover root curculio infestation is wilting of the plants, a condition also associated with plant bugs, aphids, spittlebug and leafhopper feeding.

Injury caused by this insect is most severe in newly planted alfalfa and clover fields during seasons of drought conditions.

Corn earworm (*Heliothis zea* (Boddie)) infestations were slightly higher during 1965 than during 1964. The fall corn insect survey revealed that, on a statewide basis, 11.6 percent of corn plants sampled were infested in 1965 compared to 9.4 percent in 1964 and 2.0 percent in 1963. Infestations in 1965 were still well below those of 1962 which showed a 17.6 percent infestation on a statewide basis. The heaviest infestations occurred in south-south-central (18.8%), south-southeast (19.3%) and south central (9.1%) Indiana. Corn earworm (tomato fruitworm) populations were again light on tomatoes in the commercial growing areas.

Corn flea beetle (*Chaetocnema pulicaria* Melsheimer) populations were much heavier during 1965 than they have been for several years. In late May controls were required in many areas of southern Indiana where adults ranged from 2-11 per plant. In east central Indiana late planted corn was attacked and fields in areas of Jay County had to be replanted. Populations of 10-15 adults per plant were common in the east central area. Populations of flea beetles in the rest of central and northern Indiana were generally light to medium during 1965.

Corn leaf aphid (*Rhopalosiphum maidis* (Fitch)) populations began to build up on corn the first week of July in the southern one-quarter of the state during 1965. By July 23, populations had reached peak densities in the southernmost counties, and infestations were beginning to increase in the northern three-quarters of Indiana. On a statewide basis during 1965, 7.4 percent of the corn plants sampled were severely infested (7.9 percent in 1964), while 23.5 percent had moderate infestations (20.6 percent in 1964) and 34.5 percent had light infestations (37.0 percent in 1964). Maximum infestations occurred in the northern three-quarters of the state where an average of 74 percent of the corn plants sampled were infested. The southern one-quarter had an infestation of 36 percent.

European corn borer (*Ostrinia nubilalis* (Hubner)) densities were noticeably lower during 1965 than in 1964. Indiana averaged 37.5 corn borers per one hundred plants in 1965 (59.6 per one hundred plants in 1964) on a statewide basis, and 25.8 percent of the plants sampled during 1965 were infested. The south-southwest region had the highest percent infested plants (45%) and the greatest number of borers per one hundred plants (62) during 1965. During 1964, this same area had 95.7 borers per one hundred plants. In general, corn borer populations during 1965 were very similar to those of 1963 which had 35.7 borers per one hundred plants on a statewide basis and a yield loss of 1.1 percent. During 1965 the yield loss was 1.1 percent also and there were 34.5 borers per one hundred plants as already stated.

Fall armyworm (*Spodoptera frugiperda* (J. E. Smith)) populations were again very light during 1965. This is the fourth consecutive year that this insect has been at non-economic levels.

Grasshoppers (*Melanoplus femurrubrum* (DeG.), *Melanoplus differentialis* (Thos.) etc.) were not economically important in Indiana during 1965, and no reports of infestations requiring control measures were received. Populations built up somewhat in the east central and southeast districts during the first three weeks in June, but they never exceeded 2 nymphs or adults per square foot. No adult survey was conducted by Purdue entomologists during the late summer or fall of 1965.

Harlequin bug (*Murgantia histrionica* (Hahn)) was reported severely infesting broccoli in the Corydon area of Harrison County during mid July, 1965.

Hessian fly (*Mayetiola destructor* (Say)) field populations of Race B capable of infesting Monon, Redcoat and Reed have increased in size and virulence over last year. Samples from 381 certified wheat fields showed 82 percent of the Monon fields to be infested, 92 percent of the Reed fields, and 83 percent of the Redcoat fields. Knox 62, a variety resistant to Race B populations, had only 12 percent of the fields infested. While the number of Hessian fly infested resistant wheat fields has increased over last year, the average infestation for resistant varieties is still low. The average percent infestation for Monon was 8.3, Reed 11.3, Redcoat 10.6 and Knox 62 0.6.

Knox 62 still retains its resistance in the field, but is expected to become infested in the future if it is grown over large areas, and Race C or Race D individuals capable of developing on this variety increase in number.

Wheats resistant to all known races of Hessian fly will be released to farmers in the near future.

Losses to fall cabbage from the imported cabbage worm (*Pieris rapae* (L.)) were moderate, while cabbage looper (*Trichoplusia ni* (Hubner)) populations were lower during 1965 than they have been for the past few years.

Japanese beetle (*Popillia japonica* Newman) was found in Jennings and Jefferson Counties for the first time during 1965. In Jeffersonville (Clark County) and Washington (Daviess County), Japanese beetles were taken for the first time in three years. The only agricultural infestations were again reported in the Ade area of Newton County, where corn and soybeans were damaged. Adult emergence began the first week of July and reached economic levels around July 16.

Meadow spittlebug (*Philaenus spumarius* (L.)) nymphal populations were unsually heavy in the central and eastern portions of the southern one-quarter of Indiana during May of 1965. Densities of 1-2 nymphs per alfalfa stem were present in many parts of the above areas during mid May, and adult counts of 8-12 per sweep occurred the week ending June 4, 1965. By June 11, the adults had dispersed in the southernmost areas of the state. Migration back into 4-6 inch pre-bloom alfalfa was well underway September 3, when adults averaged 3 per sweep in the southeast district. In mature, post-bloom alfalfa in this same area, adults averaged 2 per 10 sweeps on September 3. In central and northern Indiana, nymphal spittlebug populations averaged 2 to 4 per 10 stems the last week of May. By June 18 adults averaged 2 per 10 sweeps on alfalfa in central and northcentral areas of Indiana, while in the extreme northeastern area of the state, adults averaged as high as 40-80 per sweep.

Northern corn rootworm (*Diabrotica longicornis* (Say)) damage occurred throughout the state during 1965. Losses were perhaps no greater than in recent years, but more farmers were recognizing the problem. Adult emergence began the week of July 10-16 in the southern one-half of the state, and by July 23 adult densities had increased to 1-2 per silk with some corn fields in southeastern and east central Indiana having as many as 10-15 adults per silk. Scattered adult infestations were being reported from all parts of the state by July 30, and adults feeding on the tips or the corn ears were observed in many areas of west central and central Indiana the week ending August 6. The severe windstorms which occurred during late August in northern Indiana caused heavy lodging in infested fields.

Pale-striped flea beetle (*Systena taenita* (Melsh.)) populations averaged 4-8 per sweep in alfalfa during mid June, 1965 in Floyd and Harrison Counties. In Dubois and Greene Counties during the same period, populations averaged 2 per sweep, while further north in Clay, Owen and Morgan Counties, populations averaged 2 per 10 sweeps in alfalfa. These insects were also present on corn and soybeans in the above areas in mid June.

Pea aphid (*Acyrthosiphon pisum* (Harris)) infestations were first observed on alfalfa in southwestern Indiana the week ending April 10, 1965. By April 24 they ranged 9 to 35 per sweep in the southern one-quarter of the state, and had increased to scattered economic densities of up to 80 per sweep by May first. On May 8, populations had declined to 20 to 40 per sweep in the southern sections, and by May 23, pea aphid densities were down to a level of 5 to 20 per sweep in the southern two-thirds of the state. In the northern one-third of Indiana, pea aphid populations averaged 6 per sweep on alfalfa by May 29. Due to the dry conditions which existed throughout the state during May and June, aphid populations were at a seasons low on June 18 and averaged 3 to 8 per sweep on a state-wide basis. These figures were based upon samples taken from alfalfa fields that had not yet been cut the first time. Populations began to increase as cool temperatures and increased rainfall in July and August promoted lush alfalfa growth throughout the state. Densities of 20 to 40 per sweep were common during mid August in the southern one-third of Indiana, while in the northern one-third of the state, populations were in the range of 10 to 40 per sweep by September 10.

Potato leafhopper (*Empoasca fabae* (Harris)) adults were first found for the 1965 growing season in the southwest and south central areas of Indiana the week ending May 23. Populations increased slowly throughout the state until on June 18, adults and nymphs together averaged 2-5 per sweep on a statewide basis. For the rest of the season adults and nymphs averaged 2-4 per sweep on alfalfa in the southern one-half of the state and were not economically important. In central Indiana, the highest leafhopper densities occurred the last week of June and the first week of July when population in the east central area averaged 6 per sweep and population in the west central area averaged

5-8 per sweep. Economic infestations of potato leafhopper in Indiana were again most general in the northern one-third of the state. From July 16 through July 30, populations averaged as high as 16 leafhoppers per sweep in many alfalfa fields throughout the area. Yellowing was obvious in many fields during the last two weeks of July. The below normal temperatures of June and July were instrumental in preventing more serious losses from this insect, since rainfall in the northern one-third of Indiana during May, June and July ranged 2.4 to 4.2 inches below normal. The above normal precipitation of August and September, plus continued sub-normal temperatures promoted lush third growth alfalfa in the northern one-third of Indiana, and potato leafhopper populations declined to sub-economic levels for the remainder of the season.

Potato tuberworm (*Phthorimaea operculella* (Zeller)) was found in a Vigo County greenhouse infesting ripening tomatoes during April, 1965. In October, the larvae of this insect were again reported from the same greenhouse. Another infestation was reported during October in stored potatoes in Vigo County. These reports are of interest since this potato pest has been very rare in Indiana.

Sod webworms (*Crambus* spp.) infestations in corn plantings following sod caused 10-30 percent loss of corn plants during late May, 1965 in areas of Washington, Clinton and Decatur Counties.

Southern corn rootworm (*Diabrotica undecimpunctata howardi* Barber) adults were common on many crops durnig 1965 throughout Indiana. Scattered adult infestations in Boone County the first week of June caused some portions of corn fields to be replanted. These were the only economic infestations reported during 1965. Adult populations reached their peak densities (based upon black light trap collections) the week of July 17-23, when trap catches ranged from 25 to 505 on a statewide basis.

The soybean cyst nematode (*Hetrodera glycines Ichinohe*) survey was again conducted by the Division of Entomology, Department of Natural Resources in the southwestern section of Indiana. The results were negative.

The stalk borer (*Papaipema nebris* (Guenee)) was again common in Indiana during 1965. In late July, one Jefferson County cornfield had a general infestation of 25 percent. This is somewhat unusual because this insect is normally found only in the border rows.

Tobacco flea beetle (*Epitrix hirtipennis* (Melsheimer)) was unusually abundant throughout the southern tobacco growing areas of Indiana during 1965. Up to 8 adults per leaf were common on young transplants during the last two weeks of June, and treatment was warranted in many fields. By early August, tobacco throughout southern Indiana was infested with populations of 20-30 adults per plant, and feeding injury was apparent.

Tomato and tobacco hornworms (*Protoparce quinquemaculata* (Haw.) and *P. sexta* (Johan.)) were light during 1965. The highest light trap catches of these two insects occurred the week of August 21-27 in Greene County where a combined total of 105 adults were trapped, in Parke County where 106 adults were caught and in Jackson

County where 93 hornworm adults were captured. In general, populations in the northern one-third of the state were at trace numbers, while populations in the southern two-thirds of Indiana were light and very little if any economic damage resulted during 1965.

Vinegar flies (*Drosophila* spp.) were very abundant from late August until the middle of September throughout the state. Weather conditions were ideal for the buildup of this insect on tomatoes. The substantial rains and below normal temperatures that occurred during August and September produced a heavy, early tomato crop and lush weed growth. Many tomatoes rotted in the fields because processors couldn't handle the volume, and the rotting tomatoes provided excellent breeding and food material which contributed significantly to the *Drosophila* buildup.

Serious wireworm (*Melanotus* spp.) losses have been reported for several years from Decatur County, but during 1965, damage to young corn plants was slight. A report of an economic infestation in corn was received from Montgomery County during the spring of 1965, and a 36-acre field of corn in Ripley County was severely attacked.

Fruit Pests

European red mite (*Panonychus ulmi* (Koch)). The first hatch of over-wintering eggs was on schedule (when trees of the variety Red Delicious were showing pink) but early season development was at least 2 weeks slower than normal. Summer populations were below those of the past 4 or 5 years.

Codling moth (*Carpocapsa pomonella* (L.)). Caused very little loss of commercial apples in Indiana this season. Some worms and stings plagued those growers that missed important covers or tried to stretch coverage too far. In one small isolated orchard near Vincennes in which control measures were omitted, the codling moth population developed to approximately 95% infestation of the apples, thus showing the potential of this insect.

Four-spotted spider mite (*Tetranychus canadensis* (McGregor)). Apparently rare in Indiana. Only a few individuals have been identified in Vincennes' collections. They very closely resemble *T. telarius* in appearance and habits.

San Jose scale (*Aspidiotus perniciosus* (Comst.)). A few orchards are reporting a persistent population of San Jose scale which appears to be resistant to many of the currently recommended control procedures.

Strawberry leaf roller (*Ancylis comptana fragriae* (Walsh & Riley)) required control on strawberries during late May in Corydon area of Harrison County.

Oriental fruit moth (*Grapholitha molesta* (Busck)). Because of the drastic reduction in crop, many growers did not apply all of their spray program this year. As a result, there was a high percentage of flagging by oriental fruit moth in our peach orchards. This situation persisted through much of the season, and I anticipate we will have continued problems next season.

Lesser peach tree borer (*Synanthedon pictipes* (G&R)). This insect is showing a steady increase in peach orchards in southwestern Indiana.

Populations are larger than they have been for many years. Adult emergence began in April and continued into October.

Plum curculio (*Conotrachelus nunephar* (Hbst.)) was not a problem in well kept commercial orchards in southern Indiana during 1965. However, a few instances of injury occurred where proper control measures were not initiated in the petal fall period. A heavy infestation was reported in late June on apple, apricot, peach, plum and almond trees in the Columbia City area of Whitley County.

Two-spotted spider mite (*Tetranychus telarius* (L.)). While some mites were active in April, populations did not reach any economic levels until June. Northern Indiana had much more of a problem with this mite than did southern Indiana.

Red-banded leaf roller (*Argyrotaenia velutinana* (Walker)). Populations were extremely low and except for a few isolated blocks caused no commercial concern.

Forbes scale (*Aspidiotus forbesi* (Johns.)). Not a problem in 1965.

Shot-hole borer (*Scolytus rugulosus* (Ratz.)). Present, but not regarded as an economic problem in properly sprayed orchards. The insect was more prevalent than in the past 2 or 3 years.

Rosy apple aphid (*Anuraphis roseus* (Baker)). Generally contained, but isolated trouble spots did occur in southern Indiana. Some northern Indiana growers had problems this year also. The outbreaks did not take a very great toll so far as harvested apples are concerned.

Apple aphid (*Aphis pomi* (DeG.)). This aphid is persistently present and perhaps was on the increase in southern Indiana this year. It has been a common practice of many of our growers to ignore the apple aphid, or green aphid, and to aim their control measures only at the rosy aphid. This situation may soon have to be changed.

Wooly apple aphid (*Erisoma lanigerum* (Hausm.)) aerial forms are becoming more numerous in orchards in southern Indiana. There is more and more evidence that this insect is escaping normal control measures. It is not of commercial concern at present, but this aphid bears watching.

Garden webworm (*Loxostege similalis* (Guenee)) larvae heavily attacked onions in one area of Clay County during June.

First fall webworm (*Hyphantria cunea* (Drury)) infestation of the season were observed on mulberry June 5 in Harrison County and June 10 in Tippecanoe County. Webworm populations were very prevalent in woodlots and lawns in the suburban Vincennes area, and were a nuisance on the periphery of several orchards. In the Plymouth area of Marshall County, webworms moved from woodlots into adjacent blueberry plantings during early September, causing concern to growers.

Peach tree borer (*Sanninoidea exitiosa* (Say)) infestations were relatively unimportant in commercial orchards during 1965. However, apricot and peach trees in the Lafayette area of Tippecanoe County and Bridgeport area of Harrison County were attacked to the extent that many trees in nurseries and private plantings had to be destroyed.

Apple maggot (*Rhagoletis pomonella* (Walsh.)) infestations were reported on crab apple during mid September in Tippecanoe County.

This insect is not a problem in the southwestern section of Indiana where a number of commercial orchards are located.

Yellow-necked caterpillar (*Datan ministra* (Drury)) larvae were reported severely infesting apples in one area of Cass County during mid July, 1965.

Pear slugs (*Caliroa cerasi* (L.)) were reported injuring cherry trees at Osgood, Ripley County during late June.

Livestock Insects

Cattle grub (*Hypoderma lineatum* (deVillers)) activity during 1964-65 was similar to 1963-64 when high winter counts of grubs were observed in the backs of western feeder stock that had been shipped to Indiana.

Face fly (*Musca autumnalis* (DeGeer)) population trends followed those of 1964 very closely. Summer populations remained low until September when a slight buildup occurred. Generally, this insect was at sub-economic levels during 1965.

Horn fly (*Haematobia irritans* (L.)) populations were slightly higher during 1965 than they were in 1964. Populations were generally low during 1964, so the slight increase in 1965 still left the horn fly at relatively low densities.

Horse fly (*Tabanus atratus* Frabicius) were relatively light in early and middle summer. Populations became more noticeable during the latter part of September, but remained at low densities.

Horse fly (*Tabanus atratus* (Fabricius)) were relatively light in Indiana for the third consecutive year.

Stable flies (*Stomoxys calcitrans* (L.)) were present in heavier densities from late July until October during 1965 than they have been for a number of years. Not only was this insect very annoying around farms, but also in the lake area of north central and northeastern Indiana.

Pests of Man and Households

Boxelder bug (*Leptocoris trivittatus* (Say)) populations were heavier than 1964. This is based upon the increased number of reports of adult migrations into homes during the fall of 1965.

Cat flea (*Ctenocephalides felis* (Bouche)) infestations in homes were more widespread and numerous during 1965 than they have been for several years.

Carpenter bee (*Xylocopa virginica* (L.)) damage to window sills, casings and roof overhangs in areas of Tippecanoe County occurred during May of 1965.

Very few reports of cluster fly (*Pollenia rudis* (Fabricius)) infestations were received from homeowners during 1965.

The giant hornet (*Vespa crabro germana* (Christ)) was collected for the first time in Indiana during 1965. One adult was collected on June 29, in the New Albany area of Floyd County. Two additional collections were made later in the summer, one in Washington County and one in Clark County.

Yellow jacket (*Vespula maculifrons* (Buysson)) populations were unusually heavy in domestic situations throughout Indiana. These insects were very troublesome during the State Fair at Indianapolis.

Japanese weevil (*Calomycterus setarius* Roelofs) was reported severly infesting a home at Logansport, Cass County. The infestation was heavier than anyone remembered seeing for many years.

Larder beetle (*Dermestes lardarius* L.) reports were conspicuous by their scarcity during the spring and summer of 1965.

German cockroach (*Blattella germanica* L.) continued to be the chief pest in eating and food processing establishments. Suspected resistance to chlorinated hydrocarbon insecticides has been reported.

Asiatic oak weevil (*Cyrtepistomus castaneus* (Roelofs)) migrations into homes in extreme southern Indiana began in mid June and continued throughout the summer. This insect was considered to be rather rare in Indiana prior to 1965, and there were never more than a few reports of infestations in any year prior to 1965. Adults were also common on alfalfa in the south central area of the state.

Strawberry root weevils (*Brachyrhinus ovatus* (L.)) began invading homes in southern Indiana in June and continued throughout the summer, spreading northward as the summer progressed. The populations during 1965 were heavier than 1964, which in turn were heavier than normal.

Subterranean termite (*Recticulitermes* spp.) reports were fewer during 1965 than in 1964. These insects remain the major pest of structures in Indiana.

Dog ticks (*Dermacentor variabilis* (Say)) and (*Rhipicephalus sanguines* (Latr.)) were heavy in central Indiana during late spring and early summer.

Bald-faced hornet (*Vespula maculata* (L.)) populations were reported at the highest levels ever observed in the metropolitan Indianapolis area during 1965.

Turf, Tree, Shrub and Forest Insects

The Columbian timber beetle (*Corthylus columbianus* Hopk.) was recovered from sycamore; this represents a new record for the state. In general, populations were at low densities throughout Indiana.

The walkingstick (*Diapheromera femorata* (Say)) is represented by high population densities in one Starke County stand. Black oak dominates the stand but white oaks are present in small numbers and are also fed upon. High populations have been observed for six continuous years and there is evidence that this outbreak has been maintained for over ten years. This annual outbreak contrasts with Michigan, Minnesota and Wisconsin populations which appear in alternate years only.

An ambrosia beetle (*Xyloterinus politus* (Say)) was present in Tippecanoe County in silver maple (new county record) and in silver and red maple in Dubois County.

European pine shoot moth (*Rhyacionia buoliana* (Schiffermuller)) populations were heavier in 1965 than for the past several years.

Honey locust mite (*Eotetranychus multidigituli* Ewing) continued to cause defoliation of thornless honey locust trees in August. Trees weakened by transplanting or other injury appeared to be most severely damaged.

The leafroller (*Tortrix pallorana* Rob.) a pest of recently transplanted pine trees, was hardly noticeable in 1965.

The brown race of the oystershell scale (*Lepidosaphes ulmi* (L.)) continues to be destructive on redbud, silver maple and ash. The overwintering eggs hatched about a week earlier than normal.

The mimosa webworm (*Homadula albizziae* Clarke), a pest of mimosa and honey locust trees which had been of less importance during the 1964 growing season appears to be building up into destructive numbers again. Many trees were heavily webbed in August.

The maple bladder gall (*Vasates quadripedes* (Shimer)), a common problem on silver maple trees, continued to be the source of many inquiries throughout the state.

The eastern tent caterpillar (*Malacosma americanum* (Fabricius)) population was very heavy in the southern 1/3 of the state and was noticeable northward to the Michigan-Indiana state line. Heavy infestations (8 to 15 webs per tree) were noticeable in many southern locations. Locally heavy migrations of the larvae caused concern in southern counties.

European pine sawfly (*Neodiprion sertifer* (Geoffroy)) populations were heavier in 1965 than they have been for the past two years. Damaging infestations in commercial pine plantations were reported from Hamilton, Jasper, Tippecanoe, and Whitley Counties.

The pales weevil (*Hylobius pales* (Herbst)) was increasingly common in Brown, Elkhart, Jennings, Jefferson, Knox, Marion, Monroe, Spencer, Tippecanoe, Warrick and Vanderburgh counties. Many red and Scotch pine trees were killed and adult feeding scars were easily found on the pines in May and June.

The smaller European elm leaf beetle (*Scolytus multistriatus* (Marsh)) was more abundant in 1965 than for the past several seasons. Consequently, the number of trees showing symptoms of Dutch elm disease was larger.

The Zimmerman pine moth (*Dioryctria zimmermani* (Grote)) continues to be a problem in commercial Christmas tree plantations and nurseries. Damage was noticeable in Porter County plantings during the summer of 1965.

Sod webworms (*Crambus* spp.) while common were not as destructive to lawns as in recent years. One possible explanation lies in the fact that heavy damage occurred in 1963 and 1964 when the summer months were characterized by extended periods of drought. During 1965, the middle and late summer period was characterized by below normal temperatures and above normal precipitation, conditions which together promoted vigorous growth of lawns throughout the state, which in turn would tend to outgrow webworm damage. Another possibility is that the cool, wet middle and late summer affected the webworm populations themselves, and caused a reduction in their densities.

The southern pine engraver (*Ips grandicollis* Eichh.) and its frequent associate (*Corticeus parallelus* (Melsh.)) were found infesting red pine trees weakened by the attack of the pales weevil in Spencer County.

The maple petiole borer (*Caulocampus acericaulis* (MacGillivray)) infested several large sugar maples in Tippecanoe County.

The tulip tree callous borer (*Euzophera ostricolorella* Hulst) continues to cause trouble in Marion and Tippecanoe counties.

The tulip tree scale (*Toumeyella liriodendri* (Gmelin)) was very common on yellow poplar, causing disfiguration of trees, lawns, cars, and lawn furniture because of the black sooty mold which grows in the abundant honeydew.

The cottony maple scale (*Pulvinaria innumerabilis* (Rathvon)) was again abundant on silver maples in the Fowler area.

The spruce spider mite (*Oligonychus ununguis* (Jacot)) populations were heavy in Tippecanoe and Madison counties early in the spring. Trees were so heavily webbed that they appeared to be covered with "angle hair."

The bronze birch borer (*Agrilus anxius* Gory) continues to kill many white birch trees throughout the state. The droughty summers of the past several years undoubtedly contributed much to weakening the host trees and making them attractive to the borer.

Nantucket pine moth (*Rhyacionia frustrana* (Comstock)) population continues at low ebb in southern half of the state.

The broad-necked root borer (*Prinous laticollis* (Drury)) was found seriously damaging a shipment of hemlock in a nursery in Marion County.

The fall cankerworm (*Alsophila pometaria* (Harris)) populations, while noticeable, did little damage in 1965.

Bagworm (*Thyridopteryx ephemeraeformis* (Haworth)) populations were generally heavier during 1965 than in 1964. Both evergreen and deciduous trees and shrubs were damaged.

Elm leaf beetle (*Galerucella luteola* (Muller)) adult activity in homes during the spring months was unusually heavy in 1965, and first generation larval infestations on Chinese elm were much heavier and widespread than in recent years. Apparently the cooler than normal middle to late summer temperatures and the normal to above normal precipitation curbed second generation larval development, since reports of damage declined toward the latter part of the summer, and the number of reports of adults entering homes in early fall were no more numerous than in previous years.

Sycamore Lace bug (*Corythucha ciliata* (Say)) caused less damage to trees than in recent years.

Fletcher's scale (*Lecanium fletcheri* Cockerell) was less troublesome on yews than in 1964.

The white-marked tussock moth (*Hemerocampa leucostigna* (J. E. Smith)) caused little concern in 1965.

Juniper tip midge (*Oligotrophus* spp.), a pest of cannaert junipers, was again of little importance during 1965.

May beetle (*Phyllophaga* sp.) adults defoliated pin oaks in areas of Tippecanoe and Marion counties during mid May.

Rose chafer (*Macrodactylus subspinosus* (Fabricius)) adults caused heavy damage to flowers and shrubbery in areas of Noble, Pulaski and Elkhart counties during mid June.

Lilac borer (*Podesesia syringae syringae* (Harris)) was more damaging during 1965 than for a number of years.

A barberry webworm (*Omphalocera dentosa* Grote) infestation was found damaging holly in the Martinsville area of Morgan County during August. This is a new *host* record for this pest in the United States.

Chinch Bug Control with New Insecticides[1]

George E. Gould,[2] Purdue University

A minor outbreak of chinch bugs (*Blissus leucopterus* (Say)) occurred in 1964 in an area along the Indiana-Illinois state line and encompassed parts of Newton and Benton Counties in Indiana and Iroquois County in Illinois. Some 4000 acres of millet planted in old wheat land in early July was destroyed by the feeding of second brood chinch bug nymphs combined with poor growing conditions. The dry weather of the 1964 summer was favorable for a population increase and many adults successfully survived the winter. The early spring of 1965 was wet, but the months of May, June and July were dry with rainfall 4 inches below normal in northwest Indiana and 6 inches below the average in the east-central counties. Thus, by July, isolated outbreaks were observed in the northern third of Indiana, while destructive numbers were found in four counties in west-central and seven counties in east-central Indiana. In most instance, losses were restricted to the outer 5 to 20 rows of corn adjacent to ripening and harvested wheat. These high populations afforded an opportunity to check the effectiveness of dieldrin and to test several of the new insecticides.

The history of the chinch bug in Indiana goes back to 1846 when Ball (1) reported injurious populations in Lake County. In 1881 and 1882, Forbes (10) reported serious losses from Ohio, Posey, Gibson, Greene, Rush, Sullivan, Dubois and Vigo Counties. The big chinch bug year was 1887 when losses to corn, wheat, oats and millet in the midwestern states of Kentucky, Ohio, Indiana, Illinois, Iowa, Minnesota, Wisconsin, Missouri and Kansas were over $60,000,000 (12). Although minor losses occurred at infrequent intervals during the next 34 years, the next year with a noticeable infestation was 1921 when losses were reported in the central and northeastern areas of the State (2). Again, in 1933, conditions were favorable for the insect in Lake, Benton, Newton, Porter, LaPorte, Jasper, Warren, Adams, Allen, Blackford, Jay, Wells, Huntington, Whitley, Noble, DeKalb, Steuben and Elkhart Counties. High temperatures and a shortage of rainfall continued through the summer of 1934 and Davis (3) reported serious damage in 50 counties covering the area north of a line from Knox to Randolph Counties. The author was one of four persons sent out by Purdue to demonstrate construction of creosote barriers. In that year, the Federal Government appropriated $1,000,000 to buy creosote. From this money, Indiana received over 534,000 gallons of creosote and, in addition, purchased 145,000 gallons with State money. A total of 7944 miles of barriers were erected to stop the migration of the bugs. Flint (8) states that the 1934 infestation was as heavy as, and perhaps heavier than that of 1887.

The following year, cinch bugs were not serious, but in 1936, another dry year, the two tiers of counties in northwest Indiana had destructive populations (5). Beginning in 1925, Davis published annual summaries of insect problems in the State in the Proceedings of the Indiana Academy of Science. He indicated little or no trouble from chinch bugs from 1937 to 1947 and only light, scattered infestations from 1948 through 1954. Summaries by Osmun (14) since 1956 indicate that chinch bug populations in all years up to 1963 were non-economic.

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[1] Purdue University Agricultural Experiment Station Journal No. 2687.

[2] J. V. Osmun, G. E. Lehker, D. L. Matthew, Jr., and L. Chandler assisted with certain phases of the work.

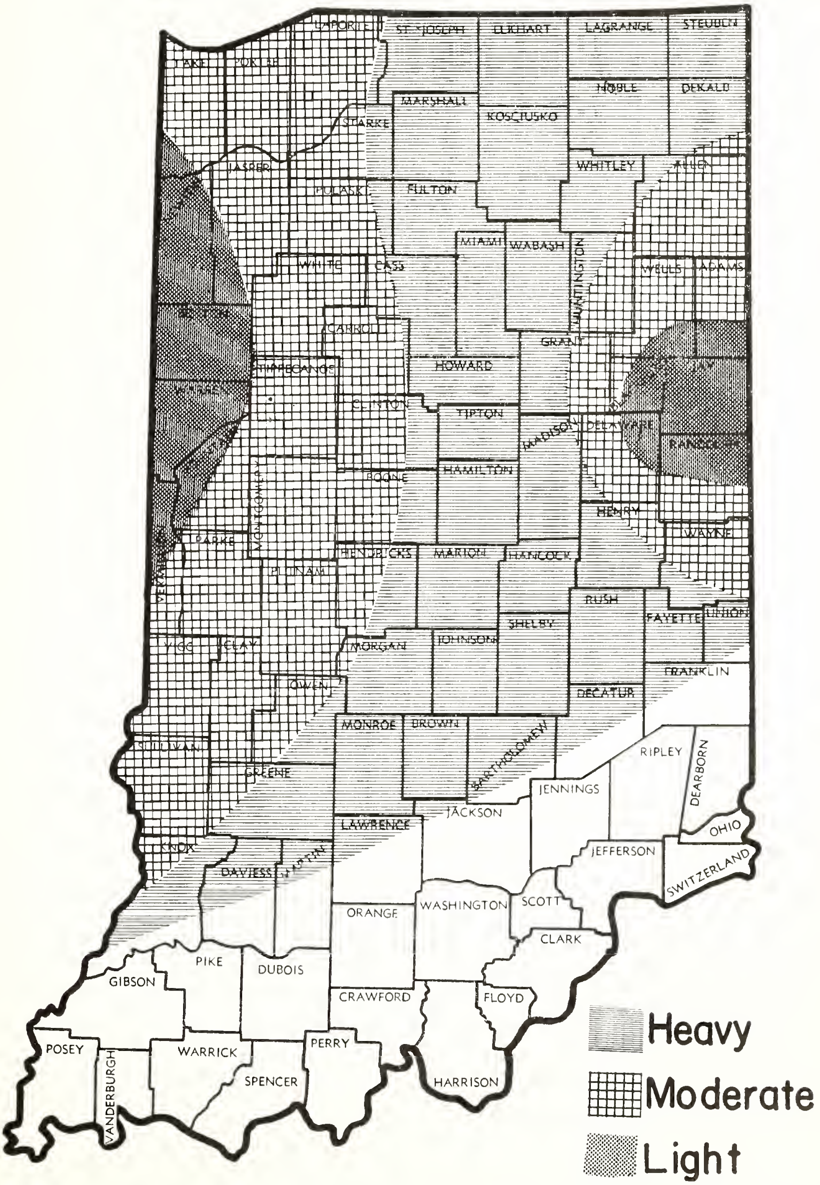

Figure 1. Map of Indiana showing areas of potential damage by chinch bugs, based on populations reported from 1934 through 1965.

Chinch bugs have always been a difficult insect to control. An example of early remedies are those suggested by Gillette (11) in 1888: 1. Plow bugs under 6 inches of soil in early summer; 2. Plow under wheat stubble; 3. Plow in fall and turn soil completely under; 4. Plant millet around small grains and, when infested, cut, plow and drag; 5. Burning of stubble and, in the winter, trash; 6. Grow large-leafed plants to create lower temperatures and unfavorable environment; 7. More manure and less crops; 8. Plant early in spring to shade the soil; 9. Neat farming, no accumulation of rubbish; 10. Unity of action among farmers; 11. Use of kerosene emulsion, coal-tar, gas lime, etc., when they seem likely to be of benefit. An early method for the prevention of migrations was the use of furrows and dust barriers, such as described by Webster (16) of Indiana in 1886.

In the 1920's and 1930's, the burning of chinch bugs in winter quarters was stressed (2, 4). A few years later, burning was no longer approved and the use of chinch-bug-proof crops was recommended (9). The use of dust and creosote barriers continued to rank first in the prevention of migrations and was the principal control measure in the big outbreak of 1934. In the mid-1940's, two toxic chemicals, dinitro-ortho-cresol and calcium cyanide, were used in the form of dust barriers (6).

Through the years, various materials have been used as sprays against chinch bugs, both clustered on the corn plants and crawling on the soil surface. Many formulations of kerosene emulsion were developed and used, but often these sprays did as much damage to the corn plants as did the insects. Richardson *et al.* (15) tested a number of materials and found that pyrethrins, rotenone and nicotine gave better control than kerosene emulsion. Kearns and coworkers (13) found that a new chemical, later called dieldrin, gave excellent kills of the chinch bug. Decker *et al.* (7) tested a number of new insecticides and found their toxicity to chinch bugs ranged in the following order: parathion best, lindane, dieldrin, endrin, aldrin, dinitro-ortho-cresol, heptachlor, dilan, chlordane, toxaphene, DDT and TDE. However, only endrin and dieldrin had sufficient residual action to stop bug migration two to four days after application.

Methods. In late June and early July of 1965, reports from the northern part of the State indicated a general, but light, infestation of the chinch bug. Some corn fields in Newton, Benton and Jasper Counties on the west and in Jay, Adams, Wells and Blackford Counties on the east had populations high enough to damage the crop in 10 to 30 rows adjacent to the wheat. Two such fields near Dunkirk in Jay County and one near Brook in Newton County were selected for testing new insecticides. In the two fields near Dunkirk, corn stands were poor and irregular. The adjacent fields of wheat were ripe but on July 5 had not been harvested. The dry, cracked soil was covered with chinch bugs migrating in all directions. The population was about 10 percent in the adult stage and the remainder evenly divided between the young red nymphs and the older black nymphs. The first two rows of corn were covered with bugs and a fourth of the plants had already been killed. The bugs were numerous and clustered on the lower stalks out some 20 rows, while beyond that the population was light and scattered. In the field north of Dunkirk, the corn plants on the low land and on the knolls was 3 to 4 feet tall, but on the sloping land, few corn seed had germinated.

During the spring, more rain fell in the Newton County area and consequently the crop was excellent. Plants in the test field were 7 to 8 feet tall, except for the four rows adjacent to the wheat. Plants in rows 1 and 2 showed the effects of chinch bug feeding and were only 3 to 4 feet tall. Most suckers and about a fifth of the plants were dead or dying. Rows 3 and 4 were taller than the outer rows and yet shorter than the remainder of the field. Clusters of bugs were found in to the 20th row and dropped off sharply beyond that. An unusual occurrence in this field was the exceptionally high population of the picnic beetle, *Glischrochilus quadrisignatus* (Say). They were found in the pollen and other debris accumulated at the base of the upper leaves and behind the leaf sheath of the lower stalk along with the chinch bugs. These beetles and the numerous blowflies present were probably attracted by the fermenting juices associated with the feeding of the chinch bugs.

In the Jay County fields, sprays were applied with a tractor-mounted 4-row sprayer. This outfit with 3 nozzles per row and 40 pounds pressure applied 25 gallons per acre. This quantity was sufficient to wet the lower stalk, but was not enough to permit any liquid to run down behind the leaf sheath. In the south field, rows 5 to 8 were treated with dieldrin, while in the north field, diazinon was applied to rows 2-5, carbaryl to rows 6-9, and dimethoate to rows 15-18. Rows 5 and 9 and beyond in the first field and 1, 12 and beyond 18 in the second field were untreated. Treated areas were not replicated.

In all three fields, a knapsack sprayer was used to apply materials to small plots which were two rows wide and 60 feet long. The application rate of approximately 250 gallons per acre was sufficient to wet the bugs and stalk and to permit some material to run down behind the leaf sheath. While this rate was excessive, it would show the ability of the insecticide to give a possible kill. In Jay County, rows 1-4 in the south field and 10 and 11 and 13 and 14 in the north field were used for small plots. In Newton County, treatments were applied to rows 1 and 2 and 3 and 4, while rows 5 and beyond were untreated.

The effectiveness of the treatments were checked approximately 48 hours after the application. An estimation of the efficiency of materials was based on general observations of insect populations and included the following: 1. the number of chinch bugs clustered on the lower stalk; 2. an estimate of dead and live red nymphs on the ground, behind the leaf sheath, or in the whorls; 3. the same for the larger black nymphs; 4. the same for adults; 5. an estimate of live bugs on the ground, especially in the loose soil around roots; 6. an estimate of live bugs hiding under dead plants, suckers and leaves; 7. estimates of numbers of dead and live picnic beetles and other insects including ground beetles, ladybird beetles, fungus beetles and lacewing flies. From these observations, a value was assigned to each plot ranging from 97 for the highest down to 5 for the poorest. Two separate observations were made in each plot, while in the case of the Newton County field, additional observations were made at 4 and 7 days after the application.

Results. In Jay County, observations 48 hours after treatment indicated poor results from the use of the large sprayer. In general, populations appeared to be lower and clusters of bugs on the lower stalk were gone. However, few dead bugs could be found on the soil or behind the leaf sheath. The ratings given included diazinon 5, dieldrin 20, dimethoate 30 and carbaryl 40. Results with materials applied with the knapsack sprayer were somewhat better and are given in table 1.

TABLE 1

Effectiveness of some insecticides in the control of chinch bugs in Newton and Jay Counties. 1965.

Material	Formulation[a]	Pounds actual toxicant per acre	Ratings[e] Newton Co. July 8	Newton Co. July 10	Jay Co. July 7
NIA 10242[b]	80 WP—C	2.6	97	90	
Parathion	2E—P	1.8	88	90	
Naled	8E—P	1.6	60	70	45
Baygon (Bay 39007)	1.5E—C	1.8	88	90	
AC 52160[c]	4E—P	2.1	40	50	25
AC 52160 + AC 47031[d]	2E—P 2E—P	3.2	52	60	35
Bomyl	4E—P	1.2	12	70	
Dimethoate	2E—P	1.3	25	70	30
Toxaphene	6E—CH	4.7	5	50	
Carbaryl	80 WP—C	2.2	35	45	
Dursban	2E—P	1.8	37	40	
Zectran	2E—C	1.8	35	35	
Matacil (Bay 44646)	80 WP—C	4.5	12	40	
Azodrin (SD 9129)	3.2M—P	1.3	33	30	
Dieldrin	1.5E—CH	1.3	—	—	25

a. Abbreviations: WP wettable powder; E emulsifiable concentrate; M miscible powder; C carbamate; P organophosphate; CH chlorinated hydrocarbon.

b. 2,3-dihydro-2, 2-dimethylbenzofuranyl-7 N-methylcarbamate.

c. 0, 0, 0′-tetramethyl 0, 0′-thiodi-phenylene phosphorothioate.

d. 2-(diethoxyphorphinylimino)-1, 3-dithiolane.

e. The rating scale was 100 for the best control down to 0 for no control.

Observations were also made on the effect of phorate granules on chinch bugs and their migration. The 10 percent granular formulation was scattered over the soil surface between rows 1 and 4 with a small fertilizer spreader. The rate of application was about 4 pounds actual toxicant per acre. Shortly after the application, it was noted that the bugs tended to avoid the granules, but none were killed. About 40 hours later, 0.75 inches of rain fell and at the time of the 48-hour examination, the odor of phorate in the field was quite strong. The bugs were perhaps scarcer in this area, but no dead were found.

In Newton County, 2 inches of rain fell during a period 6 to 12 hours after the application. At the time of the 48-hour examination, four of the 14 materials showed excellent results. Outstanding insecticides were parathion and NIA 10242, as there was little or no insect activity in their respective plots. In addition, dead chinch bugs of all stages and dead picnic beetles were everywhere, including behind the leaf sheath. After these observations on July 8, the farmer had a commercial operator spray the field with dieldrin with a high clearance sprayer. Counts made on July 10 raised some of the original ratings. However, in the original check plots, few dead chinch bugs were observed, even though the plants had received the dieldrin spray. The surprising observation was the large number of dead or dying picnic beetles scattered throughout the field. It was estimated that there were 50 beetles per square yard, while around one small corn plant near the field's edge were 530.

Several farmers in the Newton County area sprayed the corn rows adjacent to wheat with dieldrin. Most applications were made with low-pressure, low-gallonage sprayers used for weed control. Ten gallons or less of material was used per acre and the resulting control was poor. Some farmers used a second application at a higher gallonage but by that time a general dispersal of the adult bugs and heavy rains prevented further evaluation of the treatments.

Of the 15 materials included in these tests, parathion, NIA 10242 and Baygon gave outstanding results. Four other materials had low ratings after 48 hours, but showed a decided improvement by 96 hours. The poor results with dieldrin in these tests and in farmer applications was probably due to lack of coverage and the lack of exposure to the chemical.

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Genetic Variability in a Population of *Tropisternus collaris* (Fabricius)

(Coleoptera: Hydrophilidae)

Frank N. Young

A large series of *Tropisternus collaris* (Fabricius) from Lago de Ayapel, Colombia, shows relatively little variation in the extent and pattern of the markings of the dorsal surface. The general coloration is very dark in comparison to typical *collaris* from Venezuela and other areas of South America and resembles *T. paranensis* Sharp described from Parana, Brazil. The latter, however, is replaced by a different melanic form in the Matto Grosso of Brazil, and the Colombian form seems to be isolated in northwestern South America.

The Colombian form has proven tractable in the laboratory and freely interbreeds with the North American subspecies formerly assigned to *T. mexicanus* (Castelnau), (Young, 1964). The inheritance of the different color patterns, however, proves to be complex and in order to study this in more detail a number of minor variants of the pattern in the Colombian strain were selected and individuals showing the extremes were interbred. Pure lines have not yet been established because of the occurrence of inbreeding decline and what seem to be lethal or semilethal genes. All individuals of the Colombian strain are, however, inbred since all derive from the progeny of a single female.

Reduced Pronotal Blotch

Reduction of the extent of the melanic blotch on the pronotum is a characteristic of the color pattern of all the color forms of *collaris* except some individuals of the Colombian strain, *viridis* from Florida, and *paranensis* from southern Brazil.

One of the variants in the laboratory population shows varying degrees of reduction of the pronotal blotch in the form of two inverted "V"

TABLE I.

	Observed		Expected		X^2
Cross	rd	+	rd	+	
rd x rd	22	0	22	0	—
rd x rd	13	0	13	0	—
rd x rd	41	0	41	0	—
rd x +	4	9	6.5	6.5	0.96
rd x +	7	15	11	11	1.45
+ x +	21	36	14.25	42.75	1.57
+ x +	10	34	11	33	0.04

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shaped incisions of the hind margin one on either side of the middle. That is, dark pigments fails to form in these areas in the fully hardened individuals in contrast to the majority of specimens from the original sample. Extremes of this condition were selected and crossed.

The ratios in the expected column are calculated on the following assumptions:

1) rd individuals are homozygous recessives for a gene affecting pigment formation,
2) + individuals were all rd/+ heterozygotes.

Although the + type was frequent in the wild population no crosses in the laboratory produced all + type individuals. Some rd crosses produced individuals in which the reduction was feeble, but in all crosses of rd x rd the offspring showed some degree of reduction of the pigmentation.

Extension of Bronzing on the Elytra

The extent of the green bronzing which characteristically overlays the dark stripes of the elytra is variable. In some individuals of the Colombian strain the extension is so great that the entire disk of the elytra appears solid green and stripes are detectable only on the apical portions. This condition contrasts to the more usual appearance in which the elytral stripes are separated by dark bars of melanization without bronzing. Crosses between individuals showing varying degrees of extension of the bronzing suggests that the condition is due to several genes, and that dominance is not involved.

Several crosses in which both parents were intermediately bronzed produced 5 solid green, 48 intermediate, and 4 dark bar individuals. This is suspiciously close to the results expected if the intermediately bronzed individuals were heterozygous for two allels affecting this character (X^2, 0.13 not significant if intermediate phenotypes cannot be distinguished). However, crosses in which one parent was dark bar and the other intermediately bronzed gave 5 solid green, 21 intermediate, and 64 dark bar. This should not be true if the black bar individuals are truly homozygous. It, therefore, seems that more than two allels must be involved unless the phenotypic expression is influenced by other factors.

The action of several genes rather than a single pair is also indicated by the results of backcrosses of hybrids in which the original parent was intermediately bronzed and the backcross parent dark bar. Three such backcrosses gave collectively 6 solid green, 23 intermediate, and 15 dark bar. Another backcross in which the original parent was dark bar and the backcross parent dark bar gave 6 intermediate and 12 dark bar offspring.

The difficulty in analyzing these crosses lie principally in the inability to distinguish the intermediate genotypes on the basis of phenotype.

Individuals showing the solid green appearance also show a reduction in viability and most die before mating. Thus, selective elimination of the homozygotes may be taking place since the character cannot be readily assayed in larvae. One mating of solid green x dark bar produced a line in which the larvae show a peculiar thickening and darkening of the integument at the anterior portion of the thorax giving them a characteristic dumpy appearance. This is apparently due to some interference with ecdysis. These "dumpy larvae" also appear in other lines, but none of those which have survived produced solid green individuals.

Mortality and Lethal Genes

Mortality is very high in all lines of the inbred Colombian strain. In contrast, hybrids with other forms of *collaris* show greatly increased viability and larval survival.

The "dumpy" condition mentioned above occurs in several lines. It behaves as if due to a gene or genes the effects of which are expressed with great variability in the heterzygotes.

The original cross producing "dumpy" was made in November, 1964. If the condition developed before the first molt it was nearly always fatal. However, if the larvae succeeded in passing the first instar before the condition developed some completed the second molt and pupated. Two families were reared from this original cross with the following results:

	Normal larva	Dumpy larva died before pupating	Died without feeding	Adults
Family 1	24	8	8	18
Family 2	20	5	4	7

The female parent from this cross was mated with a male from another line producing dumpy larvae. Eight eggcases could be attributed to matings with this male, but only 2 larvae hatched and these died immediately without feeding.

Other crosses which also produced dumpy larvae showed even greater variability in the expression of the character. In one about 2 larvae of 20 and 4 of 19 were dumpy in two families reared. In the latter, however, all four dumpy larvae completed metamorphosis.

A cross of two offspring from normal larvae in this line produced one family with 16 normal to 13 dumpy larvae, but only 6 survived the second molt. Of these all 3 normal and 1 of the dumpy completed metamorphosis.

The dumpy trait has persisted in offspring of these original crosses, but with variable expression, and in most with greatly reduced frequency of dumpy larvae.

In another line very high early larval mortality was observed, but this trait seems to have disappeared in the survivors. Dumpy larvae also appeared in this line among larvae which survived early mortality.

Dark Larvae

Two clusters of very melanic larvae have appeared in different lines. These behaved normally, but usually died before metamorphosing. Two adults reared from them died before crosses could be made. It is tempting to consider these very dark larvae due to new mutations, but the occurrence in different lines suggests that they represent rare recombinations which have semi-lethal effects.

Masted Eggcases vs. Mastless

Most species of *Tropisternus* spin eggcases which incorporate a mast or ribbon which is presumably respiratory in function. The original female from the Colombian strain produced eggcases with a typical mast which extended above the water's surface. In her offspring, however, several females produced eggcases without sign of mast or ribbon. Eggs from these hatched normally, and the peculiarity has persisted both in the inbred lines and in hybrid crosses. The expression in some is variable, a female producing mastless, shortmasted, and fully masted eggcases at different times during her life, so it is still uncertain whether this is an inherited behaviorism or a product of laboratory conditions.

Summary and Conclusions

The data summarized above indicates that the wild population of *Tropisternus collaris* from which the laboratory population being studied was derived must have contained a considerable number of mutants. Some of these indicate genetic control of even very minor pecularities of the color pattern, but the majority of the genetic variation seems to be involved with physiological characteristics involving growth, viability, and maturation.

Several of the physiological characters are highly detrimental if not lethal under laboratory conditions. It is not certain, however, that these are equally detrimental in nature. For example, interference with ecdysis appears to be counteracted to a degree by heavy feeding. Thus under optimal conditions it may have ultimately beneficial effects in prolonging the larval life of part of the population.

The rapid departure of various lines in the laboratory from what seemed to be a characteristic wild type is also interesting. One must assume that remarkably powerful selective forces must be acting to maintain a constant type in nature. If this is true, the implications for taxonomy are clear. Varieties of this species, if not species in general, cannot be defined on the basis of morphological characteristics alone because they exist as extremely plastic populations dependent for their ultimate expression upon a complex interaction of genetic factors and environmental conditions.

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Wasps of the Tribes Stizini and Bembicini in Indiana (Hymenoptera: Sphecidae)

LELAND CHANDLER, Purdue University

As a state, Indiana is small in size with a relatively uniform climate and without striking topographic features. However, faunistic and floristic studies conducted within these political boundaries have shown a peculiar biotic admixture which seems to be not generally recognized.

The dynamics of faunistic survey have been discussed by Ross (11). Such studies transcend the "species list—key" stages, although this is the first step, and provide a more comprehensive basis for biosystematic consideration.

Wasps of the tribes Stizini and Bembicini illustrate and emphasize several of the above points. Fourteen species are recorded in this paper as occurring within Indiana. At least eight of these records are new for the state. There is the possibility that five other species may be found and these are included in the discussions. Of the 14 species listed, six are common throughout the state, whereas eight are restricted to certain portions of the state or to certain ecological sites of disjunct distribution.

Specific and generic limits are fairly well understood, but relationships of taxa, from lowest to highest, have, until recently, been unknown or poorly known and controversial. Several additional areas of study have provided evidences as striking and valuable as those of adult morphology. When behavior (4), larval morphology (6), prey records (7) and prey-carrying mechanisms (5) were integrated with adult morphology and distribution as a biosystematic unit, group relationships were more clearly elucidated.

In North America, eight subfamilies of Sphecidae are recognized (6). Keys to subfamilies and tribes were given by Borror and DeLong (1). Brues, Melander and Carpenter (2) published identification keys; however, the names now regarded as subfamilies and/or tribes were accorded familial status. The status of names and relationships found in older literature was summarized by Parker (9, 10).

Key for the Separation of Tribes

1. Ocelli normal; labrum wider than long; middle tibiae each with two apical spurs .... Stizini

1′. Ocelli distorted, median ocellus in a pit or reduced to a slit; labrum as long as, or longer than, wide; middle tibiae each with one apical spur .... Bembicini

Key for the Separation of Genera of Stizini

1. Posterior surface of propodeum strongly concave, the posterior-lateral angles compressed, wedge-shaped; second cubital cell petiolate .... *Bembicinus*

1′. Posterior surface of propodeum flat or convex, without posterior-lateral projections; second cubital cell not petiolate 2
2. Mandibles dentate; inner eye margins nearly parallel . . . . *Stizus*
2′. Mandibles edentate; inner eye margins converging at clypeus . . . . *Stizoides*

Stizus Latreille

Stizus brevipennis Walsh.—This is a very large wasp superficially resembling in size and coloration the more familiar cicada-killer, *Sphecius speciosus* (Drury). Our only record of its occurrence in Indiana is based upon specimens collected in Posey County in September, 1964, by Prof. R. T. Everly. Specimens have been seen from Warren County but these are no longer extant. *S. brevipennis* utilizes long-horned grasshoppers of the genus *Conocephalus* as prey (8).

Stizoides Guerin

Stizoides unicinctus (Say).—This wasp is jet-black except for the second abdominal tergite which is red. The wings are also black except for the apices of the fore wings which are white. *S. unicinctus* is a parasitic species in the nests of *Priononyx atratus* (Lep.). The host species is common throughout Indiana but we have only a single record of *S. unicinctus*. This specimen was taken in an extensive gravel pit south of Plainville, Daviess County (June 27, 1958) by C. E. McCoy.

Bembecinus Costa

Bembecinus neglectus (Cr.).—From May to October, 1958, an entomological reconnaissance of the Hovey Lake area (Posey County) was undertaken by the Purdue biosystematic group. On June 26, a large number of individuals of *B. neglectus* (det. K. V. Krombein) were taken from the flowers of creeping yellow watercress, *Rorippa sylvestris* (L.) Bess. The area was an extensive sand flat, all of which had been submerged by the flooding of the Ohio River during late spring. No other collections have been made of this species nor have we been able to secure additional specimens from this same area during subsequent trips. The reported prey of *B. neglectus* is leafhoppers and fulgorids (8).

Key for the Separation of Genera of Bembicini

1. Median ocellus in a pit, the borders of which are distinctly elevated 2
1′. Medium ocellus not in a pit but reduced to a transverse or semicircular slit 3
2. Tarsi without or with much reduced arolia (Male: second sternite bituberculate; female: scutum without discal marks) . . . . *Stictiella*
2′. Tarsi with conspicuous arolia (Male: second sternite non-tuberculate; female; scutum with yellow discal marks) . . . . *Glenostictia*

3. Posterior surface of propodeum strongly concave, the posterior lateral angles compressed, wedge-shaped . . . . . *Bicyrtes*
3′. Posterior surface of propodeum slightly concave, flat or convex, without pronounced posterior-lateral angles 3
4. Mandibles edentate . . . . . *Microbembex*
4′. Mandibles dentate 4
5. Anterior ocellus reduced to a transverse slit . . . . . *Bembix*
5′. Anterior ocellus reduced to a semi-circular slit, incomplete ventrally . . . . . *Stictia*

Stictiella Parker

No species of *Stictiella* has been taken in Indiana as yet but one, *S. emarginata* (Cresson), should be present in northern Indiana.

Stictiella is closely related to *Glenostictia* from which it has been separated recently (7). The two genera are probably more readily differentiated ethologically than morphologically. Species of *Stictiella* utilize adult Lepidoptera as prey; species of *Glenostictia* use adult Diptera and Hymenoptera. *S. emarginata* has been taken with a noctuid moth of the genus *Euxoa* as prey (7).

Glenostictia Gillaspy

G. pictifrons (Smith) should occur in Indiana but has not been taken. The prey of this species has been recorded (7) as bombyliid flies of the genus *Villa*.

Bicyrtes Lepeletier

Four species of *Bicrytes* have been taken in Indiana. Two additional species, *B. capnoptera* (Handl.) and *B. insidiatrix* (Handl.) have been taken in Kentucky and one or both may possibly occur in southernmost Indiana. All of the species utilize Hemiptera as nest provisions.

Key to Species of *Bicyrtes* in Indiana

1. Posterior coxae each with a tooth on the inner distal margin . . . . . *fodiens*
1′. Posterior coxae without teeth 2
2. Fore wings with a heavily clouded area in the first submarginal cell . . . . . *viduata*
2′. Fore wings hyaline or uniformly clouded 3
3. Males 4
3′. Females 7
4. Middle femora each with a basal ventral projection . . . . *ventralis*
4′. Middle femora smooth or carinate but without basal ventral projections 5
5. Flagellum entirely black; legs black and yellow . . . *quadrifasciata*

5′. Flagellum, in part, ferruginous; legs wholly ferruginous or black and ferruginous 6

6. Scape, basal segments of flagellum and legs ferruginous .... *insidiatrix*

6′. Scape and basal segments of flagellum black above, yellow or ferruginous below; legs black and ferruginous .... *capnoptera*

7. Pygidial area strongly demarced by lateral ridges... *capnoptera*

7′. Pygidial area lacking 8

8. Mesopleura each with yellow spot .... *quadrifasciata*

8′. Mesopleura immaculate 9

9. Flagellum black; legs black with yellow or ferruginous; apex of tergite 6 black .... *ventralis*

9′. Flagellum, legs and apex of tergite 6 ferruginous.... *insidiatrix*

B. fodiens (Handl.)—This species has not been recorded previously from Indiana. Our record is based upon a single specimen taken in Jackson County, August 5, 1938, on tulip poplar, by R. L. Schnell. The specific determination was by Miss Grace Sandhouse.

B. quadrifasciata (Say).—This is a common species throughout the western half of Indiana. It has been collected from June 19 to September 23 in the following counties: Daviess, Gibson, Greene, LaPorte, Marshall, Porter, Posey and Tippecanoe.

B. ventralis (Say).—Our records indicate that this species is more widely distributed than is *B. quadrifasciata* but it is less numerous in terms of individuals taken. Collection dates range from June 6 to October 1 from the following counties: Clark, Daviess, Gibson, LaPorte, Marshall, Newton, Porter, Ripley, Starke, Tippecanoe and Vermillion.

B. viduata (Handl.).—Within all insect groups there occurs, on occasion, a record which raises questions as to the accuracy of identification or labeling or to the status of the record (i.e., an isolated specimen which may have been transported or an established population). Our record is based upon a single female collected September 11, 1952, on *Solidago* sp., at West Lafayette (Tippecanoe Co.) by the author. *B. viduata* has been collected previously in Utah, Arizona and Texas (7, 3). The wings of this specimen are badly worn but the body coloration is bright.

Microbembex Patton

M. monodonta (Say) is the only species in the genus which occurs in Indiana. It undoubtedly occurs throughout the state and is usually abundant. Our collection dates in Indiana range from June 1 to October 2 from the following counties: Clark, Daviess, Newton, Porter, Posey, Ripley and Tippecanoe. The prey of this species is diverse, including both immature and adult insects, living or dead, and even parts of insects (3).

In this species there are two color forms. In one, the light markings are ivory or greenish-white and these individuals are always females. In the other, the light markings are bright yellow, and these individuals are predominantly males.

Stictia Illiger

The so-called "horse guard," *S. carolina* (F), is our only species. The common name stems from the behavior of the females which commonly patrol among herds of livestock searching for their principal prey, tabanid flies. Most farmers in the lake-sand ridge area of northern Indiana recognize this species and know of its beneficial habits.

Records of collection range from July 18 to September 12, in the following counties: Gibson, Jasper, Marshall, Montgomery, Owen, Starke, Tippecanoe and White. Earle Cross and I observed a tremendous assemblage of males on button-snakeroot, *Eryngium yuccaefolium* Michx., in the prairie area north of Monon (White Co.), August 13, 1958.

Bembix Fabricius

Five species of this widespread genus have been recorded from Indiana and a sixth species, *B. belfragei* Cresson, probably occurs. The work of Evans (4), cited earlier, details the behavioral characteristics of all species treated here.

Key to the Specie of *Bembix* in Indiana

1. Males (antennae with 13 segments, abdomen with 7 segments, without a sting) 2

1′. Females (antennae with 12 segments, abdomen with 6 segments, with a sting) 6

2. Without processes on sternites 2 and 6. (Sternite 7 reduced to a spine which is grooved ventrally; middle femora smooth) .... *pruinosa*

2′. With processes on sternites 2 and 6 3

3. Lateral processes on sternite 6 in addition to prominent median process .... *nubilipennis*

3′. Without lateral processes on sternite 6 4

4. Process on sternite 6 bifurcate at apex .... *sayi*

4′. Process on sternite 6 entire at apex 5

5. Sternite 2 with a large, median, laterally compressed, slightly hooked process; process on sternite 6 a transverse ridge, not sharply pointed but slightly curved on each side of midline .... *belfragei*

5′. Sternite 2 with a prominent median tubercle; sternite 6 with a small median process which is pointed and obliquely directed backward; sternite 7 with a median carina pointed posteriorly .... *spinolae*

6. Dorsal surface of ultimate tergite strongly wrinkled longitudinally .... *belfragei*

6'.	Dorsal surface of ultimate tergite pitted or smooth, not wrinkled	7
7.	Clypeus with black area basally; fasciae on scutellum, metanotum and propodeum; second tergal fasciae never with a tendency to enclose black spots	*pruinosa*
7'.	Clypeus without black area basally	8
8.	Second and third tergal fasciae enclosing black spots; lateral spots on sternites 1-5 or 2-4	*sayi*
8'.	Third tergal fasciae never enclosing black spots	9
9.	Wings infumated medially; lateral spots on sternites 2-5; second tergal fasciae usually enclosing spots	*nubilipennis*
9'.	Wings hyaline; lateral spots on sternites 2-4; second tergal fasciae without enclosures	*spinolae*

B. nubilipennis Cr.—This species probably occurs throughout the state. Its nesting habits differ from those of other species in that it utilize areas of hardpacked clay such as baseball diamonds, poultry yards, parking lot edges, etc. Dates of collections range from June 9 to October 17 from Clark, Harrison, Jefferson, Montgomery, Posey, Ripley and Tippecanoe counties.

B. pruinosa Fox.—This is a species confined to areas of extensive sand. It occurs throughout the Dune area of Lake Michigan and has also been taken from the large gravel pits in Daviess and Tippecanoe counties and from the alluvial sand flats in Posey County. Collection records range from June 29 to July 29.

B. sayi Cr.—Not recorded previously from Indiana, *B. sayi* is a species found most often in upland sand areas. We have taken it from two counties, Crawford and Tippecanoe. It is not uncommon in the latter. Collection dates range from July 4 to August 26.

B. spinolae Lep.—This is the most abundant and widespread species of bembicine wasp in Indiana. Dates of collection range from June 6 to October 30 from the following counties: Carroll, Daviess, Decatur, Gibson, Greene, Hamilton, Kosciusko, LaGrange, LaPorte, Marshall, Newton, Noble, Posey, Ripley, Tippecanoe, Vermillion and White.

B. texana Cr.—These are the first Indiana records for this species. It has been taken from two localities, Daviess and Posey counties, from June 26 to August 26. *B. texana* is reported to nest in areas of hard-packed sand and clay.

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Parasitism in a Population of the Bagworm (*Thyridopteryx ephemeraeformis*)

Gertrude L. Ward, Earlham College

In October, 1962, 484 bags of the bagworm, *Thyridopteryx ephemeraeformis* (Haworth) (Lepidoptera: Psychidae) were collected from a white pine (*Pinus strobus*) plantation near Metamora, Franklin County, Indiana. As a larva, this moth is a serious pest of ornamental evergreen trees and shrubs, and occurs to some small extent on deciduous trees. Various controls have been used against it.[1] Predation by birds is probably slight after the bag has been constructed.

Some of the bags showed empty pupal cases of the escaped males, and others exhibited small holes of the kind often made by hymenopteran parasites. The 484 bags were opened and their contents were analyzed.

Observations

It was obvious that bagworms had reached adulthood in 404 bags, while larvae were found in 80 bags. Males had emerged from 11 (2.3%) bags, 19 (3.9%) contained eggs, and 454 (93.8%) bags contained either dead bagworms or evidence of parasitism. Of the adults, 305 were females and only 99 were males, a 3:1 ratio.

A total of 255 females (52.7%) had been parasitized, 31 (6.4%) were dead with no visible parasitism, and 19 (3.9%) contained eggs. Of the males, 77 (15.9%) had been parasitized, 11 (2.3%) had emerged from their pupal cases and flown off, and 11 (2.3%) were dead with no visible parasitism. Parasitism was evident in 32 (6.6%) of the larvae, and 48 (9.9%) were dead without visible parasitism.

One of the unusual features of this population is the high percentage of females. At other locations, usually with smaller samples, there is a ratio much closer to 1:1. Also, the number of eggs per bag averaged close to 300, which is somewhat less than I have counted in bags from other host trees. For example, from arbor vitae (*Thuja occidentalis*) a count of eggs from 27 bags averaged 533.

In addition to parasites, one of which was identifiable as *Itoplectis conquisitor* (Say), there appeared to be several hyperparasites.

Conclusions

Although at least 75.2% of the population was lost by parasitization, the 19 bags which contained eggs were apparently enough to ensure a carryover to the following year, when 26 bags were collected. All of these contained adults, of which 24 were female and 2 were male. No males had emerged, and 22 of the adults were dead, leaving 4 with eggs. The number of eggs averaged 348, and totaled 1391. Parasitized females totaled 15, with 5 dead with no visible parasites. The two males had been parasitized.

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GEOLOGY AND GEOGRAPHY

Chairman: JOHN B. PATTON, Indiana University

LEE GUERNSEY, Indiana State University, was elected chairman for 1966

ABSTRACTS

Light Transmission Through Marble. GEORGE J. SCHNEIDER and ERHARD M. WINKLER, Dept. of Geology, Notre Dame.—Translucent marble panels have been used for special interior light effects since ancient times. In this series of tests the light transmission rates of 5 calcite, 2 Mexican Onyx (aragonite), and 1 magnesite marble were measured with a sensitive photometer. Measurements were taken on slabs of different thicknesses both parallel and perpendicular to the optical axes of the grains.

The semi-log plot of light transmission versus thickness is found to be a straight line of constant slope for all the crystalline marbles. The optical equation $I_f = I_1 e^{kn}$ was applied and reduced to $K = (I_f - I_1)/n$ to define the slope of this line: k is the dispersion factor, I_1 the intensity of the source, I_f the intensity of the transmitted light, and n the thickness of the slab. It is also observed that light transmission through different orientations of the same marble differed by only a constant, with more light being transmitted perpendicular to the optic axis.

The semi-log plots of the aragonite are also a straight line but no relation exists between these or the crystalline marbles. Light transmission through different orientations of aragonite marbles is found to be the opposite of the crystalline marbles with more light passing parallel to the optic axis.

The lack of opaque pigments and the orientation of the crystals in most marbles may permit favorable light transmission through thin slabs in many marbles.

Lake Chicago Sediments in Northwestern Indiana. MARK RESHKIN, Indiana University, Northwest Campus.—Some diversity exists in the kinds of sediments which accumulated in glacial Lake Chicago in northwestern Indiana. Clays, up to 30 feet thick, dominate the lacustrine section in Porter County and range from slightly reworked clay till to thinly laminated, varved calcareous clays. These clays overlie clay till of the Valparaiso morainic system except in some post-glacial, pre-lacustrine valleys where as much as 30 feet of outwash sands and gravels intervene.

Westward, in Lake County, and contiguous with the clays are sand deposits up to 30 feet thick and ranging in composition from beach gravels to fine-grained lacustrine sands and silts. North of the Tolleston shoreline, the upper part of the lacustrine section exhibits a distinctive geomorphic expression: numerous low sand ridges oriented parallel to the shoreline. The writer suggests their possible sub-aqueous origin.

Thin organic layers, mostly peat, are found intercalated throughout the sand section in one deep exposure. In some localities the lacustrine sands are separated from the underlying clay till by as much as 15 feet of outwash sands and gravels.

In extreme western Lake County just north of the Glenwood beach few lacustrine sediments are present. The area is considered a wave-abraded plain cut on till of the Valparaiso system. A similar erosional area lies immediately north of the Calumet beach in western Lake County.

Over much of the Lake Chicago plain the lacustrine sediments are covered by eolean sheet and dune sands and scattered polludal deposits.

Peopling the Wabash Valley. BENJAMIN MOULTON, Indiana State University.—A number of studies in recent time have commented on the number of people in the Wabash Valley as compared to past numbers and possible future growth. Predictions have been made and expectations vary from study to study. The paper presented here is critique of those studies, a summary of the present population complex and an insight to the basic reasons for population growth in the next 60 years. The writer implies that a greater understanding of the reasons for growth must be understood and that change cannot be based on mathematical interpretation alone. Likewise decline evaluated on a basis of statistics does not recognize conditions that can alter such a decline.

Social Activities in Selected Middle Western Villages. JOHN FRASER HART, Indiana University.—Door-to-door interviews were conducted in selected Middle Western villages to test the hypothesis that ties of family and friendship are important factors in maintaining the observed phenomenon of village population growth in the Middle West. Most of the friends and social contacts of village people are in their own village, and the principal pastimes include watching television, visiting, and church, school, and club activities. There is little evidence, however, that a vigorous social life attracts people to the village, or keeps them there, and the hypothesis is tentatively rejected.

Ground-Water Pollution in the Mitchell Plain, Monroe County, Indiana. NANCY L. WAYNE and WILLIAM J. WAYNE.—Bacteriological contamination of private water supplies is especially common in the limestone regions of southern Indiana. Monthly testing of water samples from 28 drilled water wells and 3 springs in central Monroe County, Indiana, between June 1963 and February 1964 showed that the degree of contamination varied with the frequency of rainfall and the construction detail of the well.

All 3 springs and 3 of the wells showed large numbers of coliform organisms all 6 times they were tested; 15 wells were variable and contained coliforms from 1 to 5 times; the remaining 10 wells were free of coliforms in all tests. Bacteria count in the variable wells increased immediately after a rain and decreased notably or disappeared entirely during long periods of no precipitation. The largest number of coliform-free tests came during a 6-week period in midwinter when freezing weather kept both bacterial activity and infiltration of surface water low.

Wells that had been constructed with casing grouted to a great enough depth into the limestone to seal out all surface water were safe under all conditions. Of the 10 wells that had been cased only a few feet to the rock surface, 9 showed coliforms at least once. Wells that had been cased through some rock tended to be safe only if the casing had been driven tightly into a shaly zone in the limestone. The percentage of unsafe wells in the Ste. Genevieve and St. Louis Limestones was greater than in the Salem and Harrodsburg Limestones, probably because the upper units are thinner bedded and transmit water more readily.

The tendency of wells to become free of bacteria during periods of no rainfall means that the aquifer normally is free of pollution. Surface bacteria and sewage wastes evidently enter the poorly constructed wells as continuous or wet-weather seeps through the upper few feet of the limestone. The aquifers evidently recuperated within a few weeks through dilution and die-off when no new bacteria were added.

Airphoto Positive Lineaments in Northwestern Indiana. ERHARD M. WINKLER, Notre Dame University.—Positive relief lineaments are light colored straight lines which mark low ridges composed of coarser sediments than the underlying finer till. A field study in northwestern Indiana suggests filing these features into different groups:

a. Late glacial ice crevasse fillings caused by a stagnant or retreating ice sheet in the direction of the former ice flow in south-southeasterly direction, located between Kentland and Remington, Ind. Some of these very straight lineaments end in an eastward hook; their relief to the surrounding terrain amounts to only a few feet. The sediment is oxidized, wet, loamy, coarse sand.

b. Long, narrow, longitudinal dunes in the area of Monon and Francesville, Indiana, in east-southeast direction of constant azimuth; they frequently end with a large hook into a parabolic dune. Strong northwesterly winds blowing off the receding ice sheet may have shaped these very long dune ridges of well sorted fine grained sand.

A long narrow straight light colored ridge—locally called "Sandy Ridge"—south of Kentland and Remington is of the identical azimuth as the longitudinal dunes near Monon. Sandy Ridge is composed of wind deposited sand on the surface, whereas coarse sand and some fine gravel below depressed the till surface underneath. A glacial crevasse filling following possibly a bedrock fault appears to be combined with the formation of a longitudinal dune of Monon dune age.

Both types of relief lineaments can be easily identified on airphotos of freshly plowed or tilled fields which were photographed with black-and-white aerial films and developed and printed high contrast.

The Geography of Poverty in Indiana. LOWELL I. DILLON, Ball State University.—Although the measurement of poverty is not a simple task, the single most important factor involved is money income. After long study, The Council of Economic Advisors has defined an annual income of $3,000 as the poverty boundary for the average American family. Using this figure and information on Indiana cities and counties from the 1960 Census of Population, the following facts become apparent:

(1) Although Indiana as a whole has a somewhat smaller percentage of families living in poverty than most states, there are wide variations in the percentages of individual cities and counties.

(2) The percentage of families living in poverty in Indiana generally decreases from south to north.

(3) The percentage of families with an income of $3,000 or less is considerably greater in predominantly rural counties than in predominantly urban counties.

(4) Although major industrial counties and bordering areas may have a large total number of families living in poverty, they usually rank low in percentage of such families.

(5) The south to north decrease in percentage of families living in poverty is characteristic not only of counties but also of cities.

(6) Coal mining areas have a relatively high percentage of low income families.

(7) The problem of poverty is not merely one of Appalachia and the Deep South but is widespread in both rural and urban areas of Indiana.

Analysis of Textural and Physical Factors Contributing to the Abrasion Resistance of Some Indiana Carbonate Aggregates

TERRY R. WEST and ROBERT B. JOHNSON, Purdue University

Introduction

This study was accomplished as a by-product of research under the National Cooperative Highway Research Program (NCHRP) Project 4-2, Degradation of Aggregates, which is being carried out at Purdue University. This paper is restricted to a study of selected crushed stone aggregates in Indiana, these all being carbonate aggregates (limestone, dolomites, and combinations thereof). The overall NCHRP project encompasses various aggregate types from widespread areas.

In the aggregate degradation study the surface wearing effects or abrasion resistance of aggregates has been carefully studied in its relation to the degradation or reduction in size of aggregate masses during and after highway construction. In this regard the investigators were confronted with the problem of ascertaining what factors contributed to the abrasion of rock particles. It was through this search for contributing factors that the data for this paper were obtained.

Review of Textural Analysis of Aggregates

The analysis of aggregate textures in addition to mineral identification and weathering characteristics is accomplished through petrographic examination. This commonly consists of megascopic plus microscopic examination, the latter by use of the petrographic microscope.

Petrography in the geological sense pertains to the description and classification of rocks; this description being primarily microscopic in character. In the field of aggregates, however, there is a trend to include under this title other laboratory determinations involving techniques of mineral identification such as X-ray diffraction, differential thermal analysis electron microscope, infra-red and other analyses. A further discussion of the scope of petrography has been pesented previously by Lounsbury and Schuster (6) and Lounsbury and West (7).

Aggregate textural analysis includes the study of the grain properties such as shape and roundness and the mutual relationships of the grains characterized by orientation and interlock of the various component grains. The bibliography pertaining to rock textures in the geological field is a lengthy one but in the area of aggregates much less has been done in regard to grain texture and aggregate properties or behavior.

A relationship between grain texture and aggregate properties has been noted previously by Rhoades and Mielenz (10), again by Mielenz (9) and more recently by K. Mather (8), and by Gillott (4). West and Aughenbaugh (14) recognized the importance of texture in relation to the aggregate properties in their review of the aggregate degradation problem and Aughenbaugh *et al.* (3) reported on the effect of texture on in-service degradation.

In the past few years petrographic analyses including textural studies have been used in conjunction with other research techniques in a number of aggregate studies made at Purdue University. In unpublished studies by Schuster (12), Aughenbaugh *et al.* (3) and by West *et al.* (15), petrographic techniques were employed in addition to other research activities. Shupe and Lounsbury (11) related skid resistance of carbonate rocks to their petrographic properties, whereas Schuster and Lounsbury (13) made a study of chert and shale constituents in gravels in which petrographic studies were included.

More recently textural analysis has been used in conjunction with engineering test data and has been compared to performance. Lounsbury and West (7) reported on the effect of texture on engineering test values of selected Indiana carbonate aggregates. In addition several other investigators, for example Lemish, Hadley, and others, are working actively on the effect of texture on aggregate behavior.

The petrographic techniques used in this study were essentially those developed in the unpublished report by West *et al.* (15) in conjunction with research on aggregate degradation of base and sub-base material. At present, further refinements in technique are being made as a portion of the current research on NCHRP Project 4-2. This paper, however, does not include the results of the continuing research done for the project on this subject.

Textural Parameters

The petrographic analysis of the aggregate samples was accomplished in three steps, (1) hand specimen examination, (2) polished-section examination, and (3) thin-section analysis.

Hand specimen analysis was used to recognize surface weathering, depth of weathering and gross characteristics of the aggregate such as veins, cracks and large fossils. Polished-sections were viewed megascopically and also microscopically using a stereographic, binocular microscope. Carbonate rocks of a bedded appearance and those of an argillaceous nature were well delineated by this procedure.

In rock thin sections the following characteristics were observed:

1. Average grain size
2. Grain-size distribution
3. Grain roundness
4. Grain interlock
5. Void content
6. Weathering characteristics

The procedure used for making these measurements of thin sections has been described previously by Lounsbury and West (7).

In the laboratory additional tests of a chemical nature were made. These included insoluble residue percentage, the chemical composition of the total aggregate mass, and the insoluble residue material by X-ray diffraction techniques.

Engineering Laboratory Tests

In this study the abrasion resistance of the aggregates was used as a basis of comparison with the textural parameters and in some cases with other engineering tests. The Los Angeles abrasion machine, ASTM C 535-64T (1), was used to find the abrasion resistance of the aggregates.

The Los Angeles abrasion equipment is widely used by highway departments in the U. S. and is perhaps one of the most popular tests for aggregate quality determination. For this reason it is a useful means for comparing aggregate abrasion resistance.

The Los Angeles abrasion machine consists of a hollow steel cylinder closed at both ends in which a combination of aggregate sample and steel balls is rotated according to the test specifications (1).

Following the test, the sample is sieved. The difference between the original weight and the final weight retained by a #12 sieve is expressed as a percentage of the original weight and reported as the percentage of wear. Therefore, the higher the percentage of wear by the Los Angeles abrasion test the less the abrasive resistance of the rock.

The laboratory test results from other engineering tests were obtained for some of the aggregates. The tests included were bulk specific gravity, saturated surface dried; percent of absorption; and percent loss in sodium sulfate. Further information can be obtained from ASTM standards on these test procedures (1).

Statistical Analysis

After obtaining the textural and engineering test data a multiple regression and correlation analysis was made on the data. This method permits a simultaneous comparison of a number of independent variables to see how they affect the single dependent variable. In this analysis the percentage of wear by Los Angeles abrasion was made the dependent variable and all the other factors were designated independent variables.

This method is particularly valuable in geology because of the numerous variables that act on a single geological problem. There is no simple means of assessing the importance and interaction of these variables without some similar statistical approach.

A simple graph consisting of a straight line relationship between two variables is an example of a regression analysis. The independent variable is conventionally the abscissa and the dependent variable the ordinate. By selecting a value for the independent variable and intersecting the straight line a value for the dependent variable is obtained.

In the multiple regression portion of this analysis each independent variable is paired in turn with the dependent variable. As a result a listing of the independent variables in order of their ability to predict the dependent variable is obtained. These data are given in the form of coefficients for the independent variables used and from these a predicting equation for the dependent variable can be obtained using the independent variables.

Correlation coefficients are also obtained from this analysis. These coefficients are related to the variables through correlation theory rather than regression theory.

The correlation between two parameters or variables is indicated by a number ranging from plus to minus one. The number plus one indicates perfect correlation between two variables and zero indicates no correlation at all. The sign of these numbers can be plus or minus, plus indicates a direct correlation, for example, as A increases B increases whereas minus indicates a reverse relationship or as A increases, B decreases. Correlation does not imply any dependent variable relationship with respect to arbitrary changes in an independent variable.

Results and Interpretation

In this study four statistical analyses have been made. Twenty-five quarry aggregates were examined prior to this research which compose

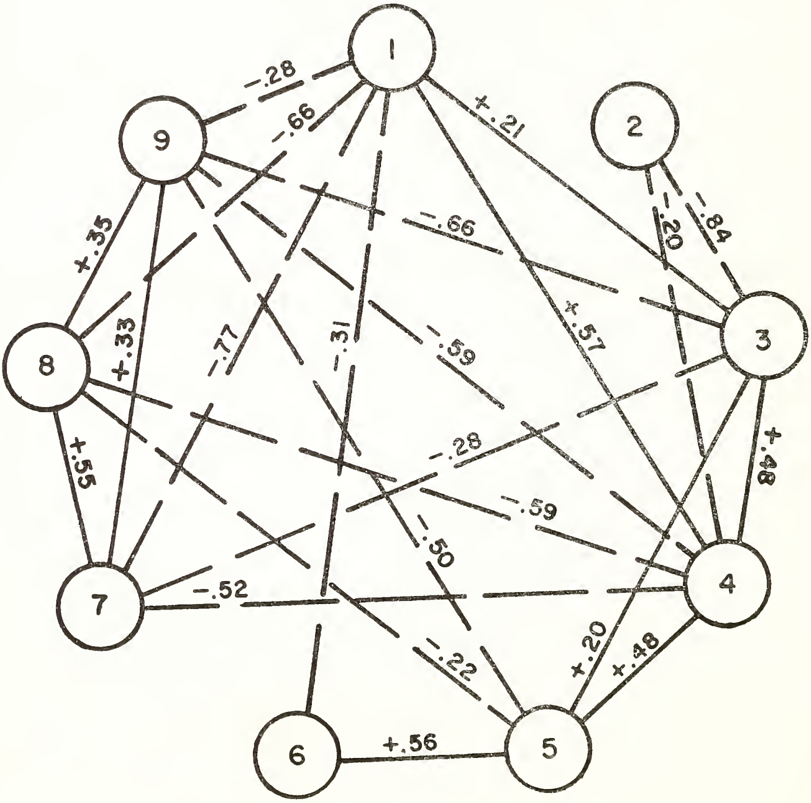

Figure 1

INDIANA I

Cluster Diagram of Simple Correlation Coefficients for Some North-Central Indiana Carbonate Aggregates

LEGEND:

1. Los Angeles Abrasion
2. $CaCO_3$ Content
3. $MgCO_3$ Content
4. Percent Voids
5. Average Grain Size (mm)
6. Grain Size Variation (mm)
7. Grain Shape—Highest number indicates most angular particles
8. Grain Interlock—Highest number indicates best interlock
9. Percent Insoluble Residue

the first analysis. The petrographic characteristics were measured in a somewhat qualitative sense using verbal descriptions and a numerical base was added for programming purposes.

Figure 1 is a simple correlation cluster diagram for this analysis. A simple correlation coefficient shows the relationship between two variables but the problem of inter-relation between the various parameters is not corrected for in this procedure. The cluster diagram shows the simple correlations between parameters measured in pairs. The coefficients which are less than ± 0.2 have been omitted as these are assumed to be of insignificant importance (5).

Some interesting observations can be made concerning Figure 1 which are summarized as follows:

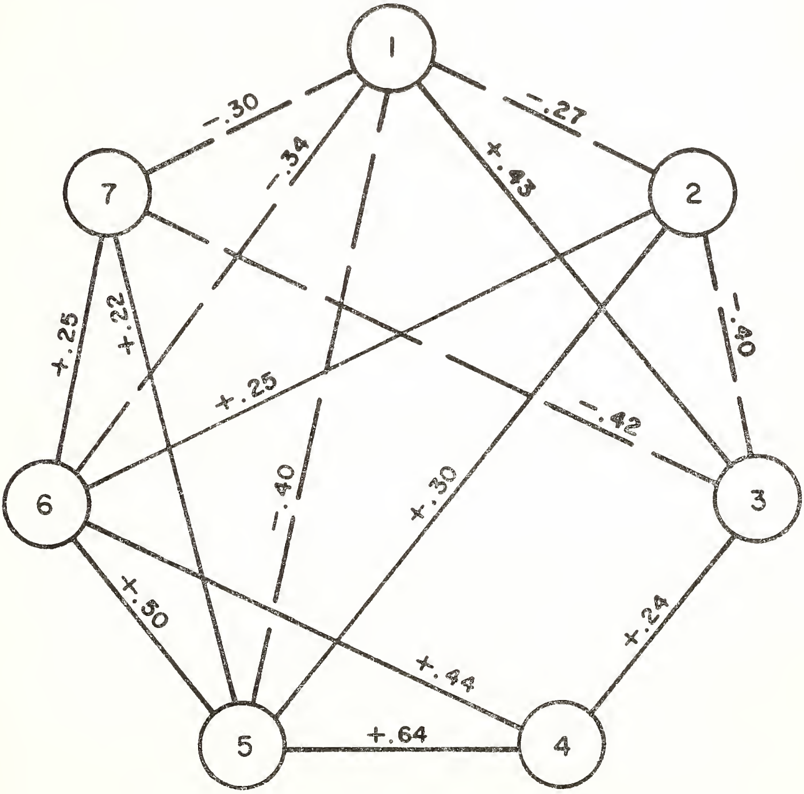

Figure 2

INDIANA I-A

Cluster Diagram of Simple Correlation Coefficients for Some North-Central Indiana Carbonate Aggregates

LEGEND:
1. Los Angeles Abrasion
2. Percent Insoluble Residue
3. Percent Voids
4. Average Grain Size (mm)
5. Grain Size Variation (mm)
6. Grain Shape—Highest number indicates most rounded particles
7. Grain Interlock—Highest number indicates best interlock

1. A positive relationship exists between percent voids and percent loss by Los Angeles abrasion, that is as the voids increase the abrasion loss increases.
2. A strong relationship between $CaCO_3$, $MgCO_3$ and insoluble residue exists. This is to be expected because together they form a closed system of 100%.
3. A positive relationship occurs between $MgCO_3$ and void content. This is due to the fact that many reef dolomites in Indiana have increased voids in comparison with their calcium-rich counterparts.
4. A negative relationship exists between percent loss by Los Angeles abrasion and interlock, that is, as the interlock becomes poorer the abrasion loss gets greater. Also the angularity of the grains decreases as the abrasion loss increases.

Figure 2 is a simple correlation diagram for the same 25 quarry aggregates as used in Figure 1, but numerically based measures were used directly when analyzing the aggregates in this case.

It can be observed in this diagram that:

1. The positive relationship between percent loss by Los Angeles abrasion and percent voids is still indicated.
2. A negative relationship between grain size variation and abrasion loss is indicated. As the aggregate becomes more dense owing to a greater range in grain size the abrasion loss is reduced.
3. The interlock and shape have a lesser effect on abrasion resistance than in Figure 1. This is probably due in part to the fact that these properties are being measured more precisely and side effects have been lessened to some degree.

Figure 3 is a third simple correlation chart. These data were obtained from about 15 quarries through the state of Indiana. In this example, engineering test data other than that for the Los Angeles abrasion test have been obtained. In addition, in-service performance data regarding aggregate degradation have been obtained as well. In this analysis the interplay between various tests, textural properties, and performance is shown. The following conditions are observed:

1. There is a negative relationship between percent loss by Los Angeles abrasion and degradation performance. As the abrasion becomes greater the aggregate is more susceptible to degradation.
2. The positive relationship between void content and abrasion loss persists.
3. A positive relationship between absorption values and bulk specific gravity is indicated.

Figure 4 is a partial correlation coefficient cluster diagram for the same 15 aggregates analyzed for Figure 3. Partial correlation coefficients are used to examine an independent variable paired with the dependent variable while the other independent variables are kept constant or the effect of their presence is kept constant. In other words, the independent

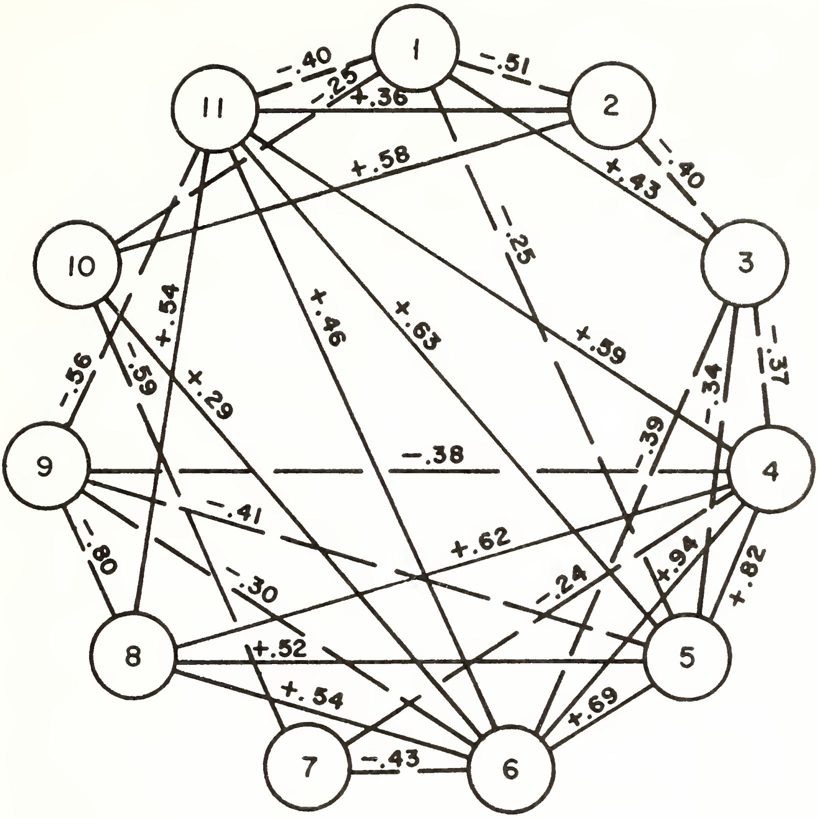

Figure 3

INDIANA II

Cluster Diagram of Simple Correlation Coefficients for Selected Indiana Carbonate Aggregates

LEGEND:

1. Los Angeles Abrasion
2. Percent Insoluble Residue
3. Percent Voids
4. Average Grain Size (mm)
5. Grain Size Variation (mm)
6. Grain Shape—Highest number indicates most rounded particles
7. Grain Interlock—Highest number indicates best interlock
8. Specific Gravity
9. Percent Absorption
10. Percent Loss—Sodium Sulfate Test
11. Degradation Value—Highest number indicates best performance

variable is truly being used independently without the side effects of other variables being noted.

In Figure 4 only five of the ten independent variables actually contribute markedly to changes in the dependent variable. It can be observed that:

1. The insoluble residue component has changed sign from minus to plus between Figures 3 and 4. This means that when the side effects are removed, a direct relation is shown to exist between these two measures.

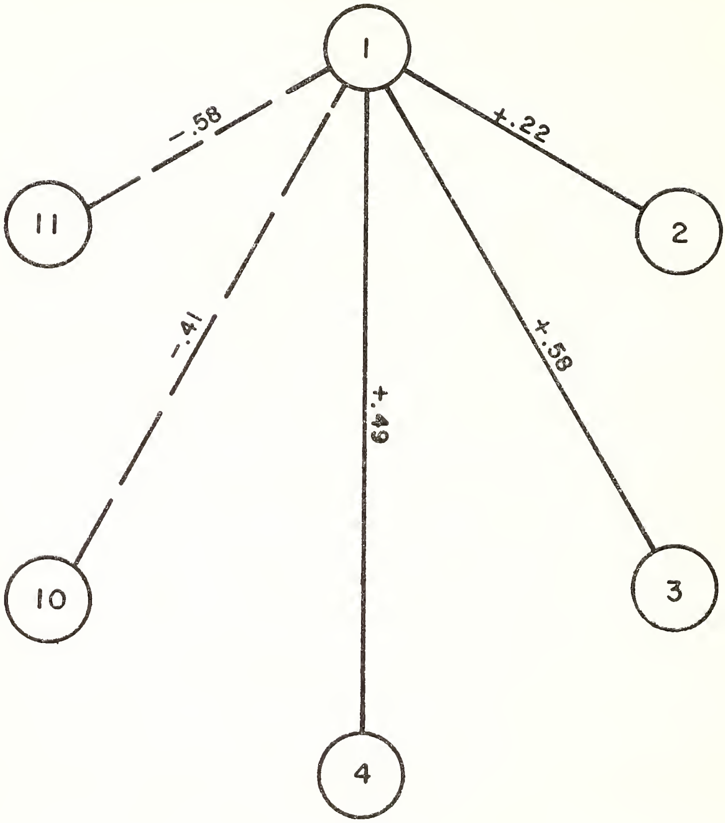

Figure 4
INDIANA II-A
Cluster Diagram of Simple Correlation Coefficients for Selected Indiana Carbonate Aggregates

LEGEND:
1. Los Angeles Abrasion
2. Percent Insoluble Residue
3. Percent Voids
4. Average Grain Size (mm)
5. Grain Size Variation (mm)
6. Grain Shape—Highest number indicates most rounded particles
7. Grain Interlock—Highest number indicates best interlock
8. Specific Gravity
9. Percent Absorption
10. Percent Loss—Sodium Sulfate Test
11. Degradation Value—Highest number indicates best performance

2. The average grain size has emerged as the strong tie with abrasion resistance rather than size distribution which was indicated by simple correlation (Figure 3).
3. The relationship between abrasion resistance and performance in degradation has been strengthened.

As a final point of discussion we can turn once more to the area of multiple regression analysis which has been discussed in the statistical analysis portion of this paper. The parameters that are significant in regression analysis are the same as those which appear as important partial correlation coefficients. In order of importance for the 15 quarry study (Figures 3 and 4) these parameters are:

1. Insoluble residue
2. Void content
3. Degradation value
4. Average grain diameter
5. Sodium sulfate loss

Together these 5 account for 55% of the variability noted in the percent loss in the Los Angeles abrasion test, that is, they predict 55% of the variability in the abrasion values noted. This means that other factors should be found to account for the remaining variation. This 55% value is somewhat better than the 38% which was obtained for the analysis in Figure 1, however.

The regression analysis yields regression coefficients as well as indicating the order of importance of independent variables. These coefficients can be used to obtain an equation for the curve which best predicts the percent of wear by Los Angeles abrasion. The equation is as follows:

$$X_1 = 32.12863 + 0.14603\ X_2 + 0.68276\ X_3 - 1.5452\ X_{11} + 0.01155\ X_4 - 0.18746\ X_{10}$$

where

X_1 = percent loss, Los Angeles abrasion
X_2 = percent insoluble residue
X_3 = percent voids
X_4 = Average grain diameter (mm)
X_5 = Grain size variation (mm)
X_6 = Grain shape
X_7 = Grain interlock
X_8 = Specific gravity
X_9 = Percent absorption
X_{10} = Percent loss, Sodium Sulfate
X_{11} = Degradation Evaluation

Acknowledgments

The authors are indebted to Mr. R. C. Parks who made the line drawings and to NCHRP which made this research possible.

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Quanitative Differential Thermal Analysis as Applied to the Thermal Decomposition of Magnesite

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Differential thermal analysis offers a technique by which the enthalpic changes that accompany thermally induced chemical and physical transformations can be estimated. In certain instances the results from d. t. a. agree with those from conventional calorimetry; in other instances the agreement is quite poor (4). This investigation uses differential thermographs of the decomposition of magnesite to test the validity of the Vold-Speil equation (8, 5). The basic equation is

$$\frac{dy}{dt} = -Ay + B + \frac{\Delta H}{C_s}\frac{df}{dt} + \frac{(C_s - C_r)}{C_s}\frac{dT_r}{dt}. \tag{1}$$

A and B are parameters dependent upon furnace construction and geometry, ΔH the total enthalpic change of the active material during the transformation, C_s and C_r the heat capacities of the sample and reference materials, f the fraction of the sample transformed after time, t, and y the differential temperature between reference and sample materials, $T_r - T_s$.

Under the experimental conditions that there is a constant rate of heating of the sample block, symmetric positioning of the reference and sample materials within the furnace, sample dilution with an inert reference material of comparable heat capacity to that of the reference material, and no thermal transformation is occurring, the solution to equation (1) is

$$y = y_s \left\{ 1 - \exp\left[-A(t - t_1)\right] \right\} + y_1 \exp\left[-A(t - t_1)\right]. \tag{2}$$

y_s represents the steady state value for the differential temperature, and y_1 the value of the differential temperature at the arbitrary time t_1. During the time in which a transformation takes place the solution is

$$A \int (y - y_s)\, dt = \frac{\Delta H}{C_s} \tag{3}$$

Integration is performed from the point at which the endotherm begins to the point where the reference and the sample have again attained the steady state temperature difference. The term $\int (y - y_s)\, dt$, is the area under the curve. The parameter A can be evaluated from a plot of log $(y - y_s)$ versus t. The region of the thermograph from its maximum to the point at which the steady state temperature difference is again realized is used to evaluate A.

Experimental

The d. t. a. apparatus consisted of the furnace and the stainless steel sample block used in the Aminco Thermoanalyzer (American Instrument Co., Inc., Silver Spring, Maryland). The block temperature and the differential temperature were monitored using chromel-alumel, inconel sheathed thermocouples (Thermocouple Products Co., Villa Park, Illinois). The thermocouple output was amplified by a factor of 114 and recorded using the Sargent recorder, model S. R. The heating rate of the furnace was programmed such that the sample block temperature increased 20° C per minute within the temperature range of 150° to 1000° C. Since symmetric thermographs were realized for magnesite decomposition with a dynamic atmosphere of CO_2, a gas flow rate of 1 c. c. per minute at S. T. P. of CO_2 was maintained through both the reference and the sample compartments.

Thermographs were made on a series of mixtures of magnesite-calcium carbonate, dolomite-calcium carbonate, and magnesite-dolomite-calcium carbonate. The $MgCO_3$ content of the magnesite was 98.95 per cent and that of the dolomite was 40.21 percent as determined by the E. D. T. A. titrimetric method (3). To make the individual mixtures known weights of each material—particle size 100 mesh or less—were thoroughly mixed by tumbling in a closed container. The thermographs of weighed samples, 0.2 to 0.3 grams, were determined; reagent grade, ignited alumina served as the thermally inert reference material.

Results and Discussion

In any sample that contained both dolomite and magnesite, the endotherm due to the magnesitic $MgCO_3$ and the endotherm due to the

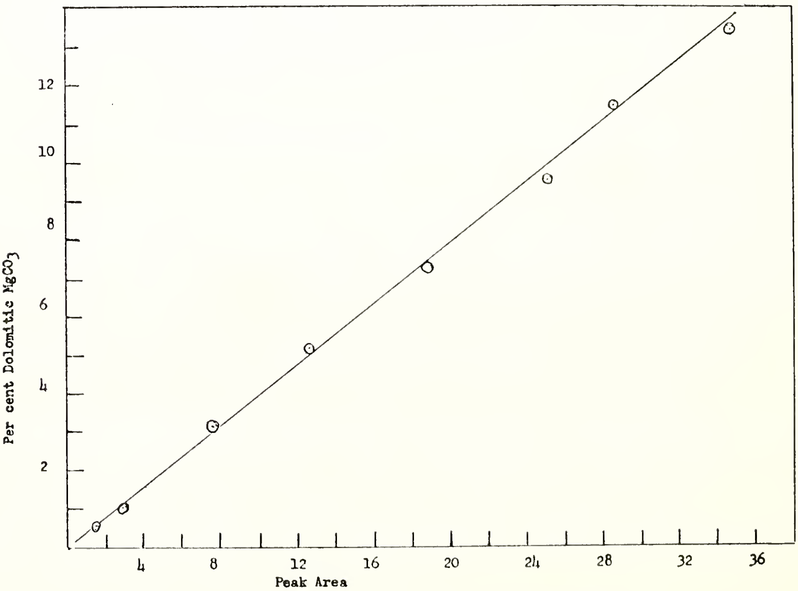

Figure 1. Percent Dolomitic $MgCO_3$ versus Peak Area

dolomitic $MgCO_3$ were at the same temperatures as the endotherms for samples of the pure substances. The decomposition temperatures in this work (peak temperature: dolomite 790° C.; magnesite 640° C.) agree with those in the literature (6, 7). The Vold-Speil equation predicts that the peak area should be a linear function of the percent $MgCO_3$ in the sample. The expected linear relationship was obtained for both magnesite and dolomite. Figure 1 is the curve for dolomitic $MgCO_3$. This curve is reproduced since the d. t. a. thermographs of samples of Putnam County, Indiana limestones indicated that $MgCO_3$ was present in the dolomitic form. It emphasizes that d. t. a. can be used profitably to estimate the magnesium content in limestone.

The enthalpy of decomposition of magnesite can be calculated by the following relationship:

$$\Delta H = \frac{(C_s)\,(A)\,(\text{Endotherm area})\,(0.402)\,(84.32)\,(100)}{(\text{Percent } MgCO_3)} \qquad (4)$$

C_s is expressed in calories per gram; ΔH has the units of calories per mole; and the factor 0.402 converts the product (A) (Endotherm area) to calories. The apparatus parameter A can be evaluated using the individual thermograph; the slope of the linear portion of a plot of $\log\,(y - y_s)$ versus time equals $\frac{-A}{2.303}$. The average value obtained for a series of eight determinations of the enthalpy of decomposition of magnesite was 15.7 kcal. mole^{-1}. Stone (6) reports the value of 10.1 kcal. mole^{-1} for its decomposition. His value was calculated by measuring its temperature of decomposition as a function of the CO_2 pressure above the sample. Ellis (1) reports the value of 28.3 kcal. mole^{-1} which was obtained through area comparison of the magnesite thermograph with the thermograph of a substance of known heat of decomposition. The most precise calorimetric value is 28.27 kcal. mole^{-1} (2).

The results of this investigation indicate that for magnesite and dolomite the predictions of the Vold-Speil equation are qualitatively observed; however, the calculated heat of decomposition for magnesite is low. Although d. t. a. may not be useful as an absolute microcalorimetric tool in the study of carbonate decomposition, it is demonstrated that the technique is quite applicable to the determination of the magnesium content of limestones.

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The Reversal of Racoon Creek at Atherton Island, West-Central Indiana[1]

WILLIAM J. WAYNE, Indiana Geological Survey

Atherton Island in southwestern Parke County and northern Vigo County is one of the more intriguing features of stream reversal and circumalluviation along the Wabash Valley (fig. 1). Several ideas have been advanced for the cause of the derangement of drainage that produced it, particularly Hobbs' (9) suggestion that diastrophic forces had diverted the stream, the ice-dam hypothesis of Dryer (2), and the proposals of Bartle (1) and Fidlar (3) that sand dunes blocked and reversed the drainage. None of them has seemed fully convincing to some geomorphologists who have examined the area.

Dryer (2) observed that the river that cut the bedrock valley of Raccoon Creek between Mansfield and Terre Haute had been a much larger stream than present Raccoon Creek. The upper reaches of the bedrock valley of Raccoon Creek headed north of Indianapolis (11). Dryer suggested that an ice dam probably blocked the mouth of Raccoon Creek valley south of Atherton during Illinoian time, creating a lake that drained to the north past Mecca. Further cutting, he reasoned, took place during Sangamon time. During the Wisconsin glaciation he thought the Raccoon drainage temporarily reused its old valley below Rosedale, but that after the glacier had melted, the stream returned to the northern route.

Bartle (1) reviewed previous suggestions on the reversal of Raccoon Creek and then proposed that the diversion was entirely postglacial. He thought Dryer's ice-dam hypothesis unlikely, because if the glacier melted from south to north, the ice would have opened the southern route first while the valley was still blocked with ice at Montezuma. To account for a postglacial deflection, Bartle (1) proposed that an accumulation of dunes southeast of Atherton Island blocked the mouth of Raccoon Creek and diverted the stream northward through a tributary and across a low divide near Coxville into a tributary of the Wabash. In a footnote, he (1) added a suggestion by Tucker that the outwash accumulation at the mouth of Raccoon Creek along the Wabash could have contributed to the damming and reversal of drainage.

The currently accepted explanation is Fidlar's (3) modification of Bartle's sand dune-deflection hypothesis. Fidlar suggested that the present trough north of Coxville was cut by glacial meltwater through enlargement of a tributary of Raccoon Creek, and that the diversion and reversal of drainage were accomplished when the accumulation of sand dunes in the valley below Rosedale blocked southwestward flow of the stream after the ice had melted from the area.

Dune sand is loose, and it is readily moved by running water, especially by streams in flood; therefore an accumulation of dune sand is

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[1] Publication authorized by the State Geologist, Indiana Department of Natural Resources, Geological Survey.

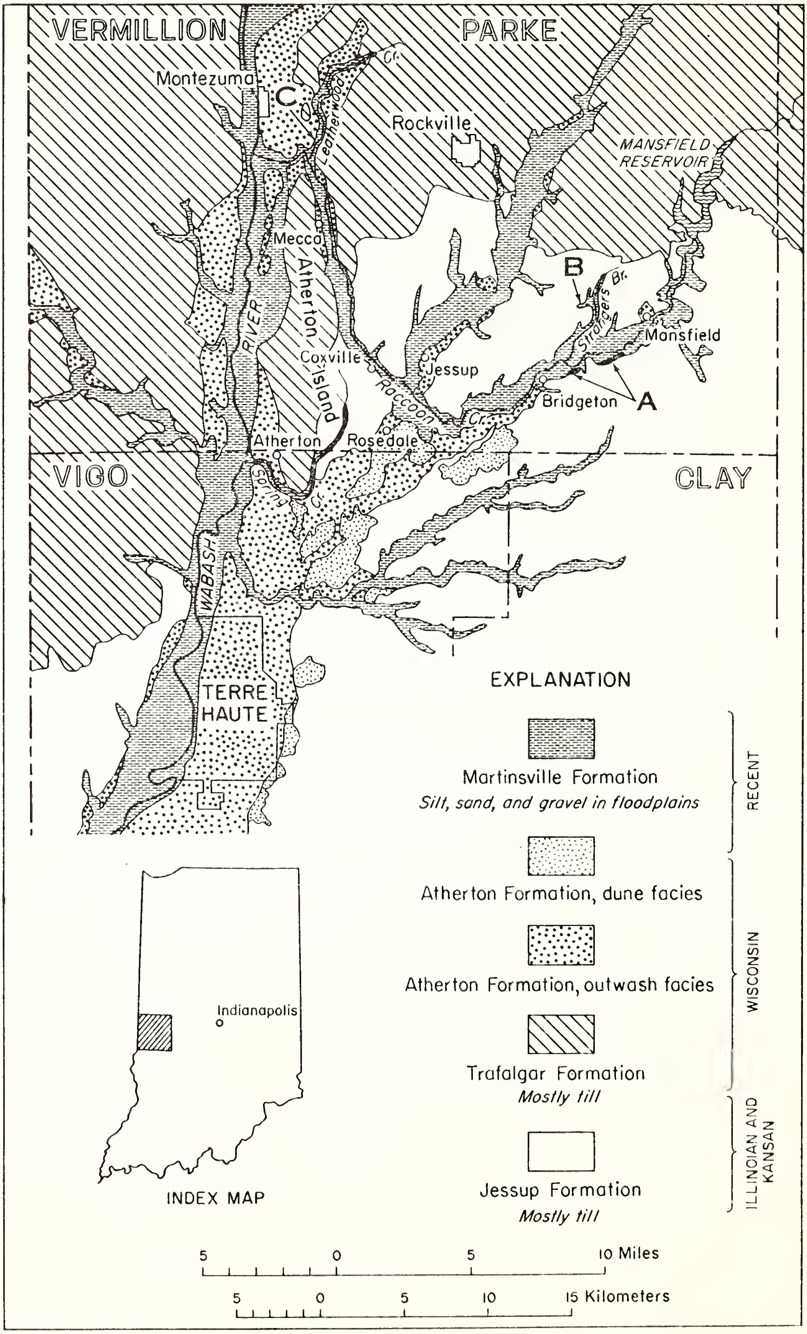

Figure 1. Map showing glacial geology of Raccoon Creek and vicinity (from Wier and Gray, 1961).

not likely to have been an effective dam that would have blocked and diverted a stream the size of Raccoon Creek. Recent studies of the glacial geology of Raccoon Creek valley between Mansfield and Terre Haute have provided data that permit the development of an additional hypothesis on the cause of the deflection.

Glacial Geology of Valley of Raccoon Creek

The bedrock valley of Raccoon Creek is filled with sands and gravels that are Kansan in age. Glacial sediments of the Cloverdale Till Member (Kansan Stage) of the Jessup Formation (12) are exposed in the lower parts of stream banks and road cuts in the Raccoon Creek valley. Flood-plain sediments of Yarmouth age are exposed in stream bluffs near Mansfield (Site A on fig. 1) at the present flood-plain level (10). Illinoian proglacial stratified clayey silts (part of the Atherton Formation, lacustrine facies) overlie the Yarmouth sediments and indicate that the valley was blocked at least temporarily, but the lacustrine sediments are overlain by thick outwash sands and gravels (Atherton Formation, outwash facies) as well as ice-laid sediments of the Butlerville Till Member (Illinoian Stage) of the Jessup Formation.

Significant enlargement of the gorge from Coxville north could have taken place during Illinoian or Kansan time. Part of the valley did exist as a tributary of Raccoon Creek, but the southern end of it has been filled with drift of Illinoian age that is being excavated by Spring Creek. The rock-walled narrow at Coxville is a diversion created during the retreatal phase of the Illinoian or an earlier glaciation, perhaps by meltwater of an ice-marignal stream.

The sediments of Wisconsin age that underlie the 2-mile-wide abandoned valley segment between Rosedale and Terre Haute are gravel and sand overlain by an uneven veneer of dune sand (fig. 1). This is the type area for these two facies of the Atherton Formation of Wayne (12). The surface is a plain that slopes gently from west to east and is covered with low dunes (13).

Upstream from Rosedale, progressively finer-grained sediments underlie terraces along Raccoon Creek. Silty sands and gravels of the Atherton Formation 2 miles below Bridgeton grade within a mile into sandy silt. Above Bridgeton few terraces are present, but fossiliferous shallow-water silts (Atherton Formation, lacustrine facies) underlie some low benches in small tributary valleys, and silt of either loessial or lacustrine origin caps low terraces underlain by Illinoian sand and gravel (Atherton Formation, outwash facies) in the main valley.

Although little can be said about the position of the Illinoian or Kansan ice margin in the vicinity of Raccoon Creek except by analogy, the extent of the ice during Wisconsin time can be rather readily determined. The Illinoian ice may have followed a similar pattern of lobation both during advance and retreat across this area.

The east margin of the Wisconsin glacier trended almost due southward across Atherton Island at the time of the maximum advance of the ice (fig. 2A). Meltwater poured southward down the narrow gorge from Mecca to Coxville. Although the glacier was too thin to spread across the upland, the ice margin extended southward down the Wabash Valley and into the mouth of Raccoon Creek along Spring Creek about 2 miles southeast of Atherton, where it built a broad outwash plain into the wide valley below Rosedale. The outwash plain extended toward Bridgeton as a delta into a lake that formed in Raccoon Creek valley upstream from the ice and outwash dam. Meltwater during both Illinoian and Wisconsin glaciations and perhaps normal erosion during Sangamon time had enlarged the valley of a former tributary of Raccoon Creek along the east side of Atherton Island. This trench is partly filled with cross-bedded sand and gravel. Terraces along the lower valley of Raccoon Creek are 530 feet in altitude, as is the surface of the Shelbyville Terrace, the upper level of valley fill (Atherton Formation, outwash facies) along the Wabash and in the abandoned segment of Raccoon Creek. Upstream along Raccoon Creek, however, the surfaces of Wisconsin terraces on Atherton lacustrine silts rise to the northeast and, along Strangers Branch, are 600 feet above sea level (Site B on fig. 1).

Hypothesis to Explain Drainage Reversal

Probably no single hypothesis is adequate to account for the diversion of Raccoon Creek. The initial blocking of the mouth of the valley northeast of Terre Haute probably took place when ice from the Lake Michigan Lobe lay across it and dammed the valley (fig. 2A). Lake sediments attest to that during both the Illinoian and the Wisconsin glaciations. During the Illinoian Age, the lacustrine phase was followed by outwash deposition when the East White Sublobe of the Ontario-Erie Lobe of the ice reached the part of the valley near Mansfield and by till when ice covered Raccoon Creek. Similar events, the filling with outwash gravels and deposition of a till cover, did not take place during the Wisconsin Age because the ice stopped short of Raccoon Creek. During both glaciations it would be reasonable to assume that some stagnant ice may have remained in the mouth of the valley near Terre Haute after a route down the Wabash had opened between the ice margin and the west side of Atherton Island. If such a dam existed, lake water probably would have drained through the outlet to the north (fig. 2B).

Some bits of field evidence seem to indicate that the surface of northern and central Indiana may have been depressed isostatically during the Wisconsin glaciation from the weight of the overriding glacial mass. Harrison's (8) study of the ice thickness in central Indiana indicated that ice in the East White Sublobe thickened abruptly north of the margin. Because Wisconsin ice in the Wabash trough failed to spread eastward beyond the crest of Atherton Island, it may not have been more than 200 feet (60 meters) thick near the margin, but it probably would have increased in thickness to more than 1,000 feet (300 meters) about 10 miles upstream in the glacier (fig. 2A). Such ice thicknesses should have caused some isostatic depression during the few hundred years this area was covered by ice; rebound would not have been instantaneous but should also have required a few hundred years.

Gutenberg (7) has suggested that the amount of isostatic depression to be expected under an ice cap should, at equilibrium, be one-third of the

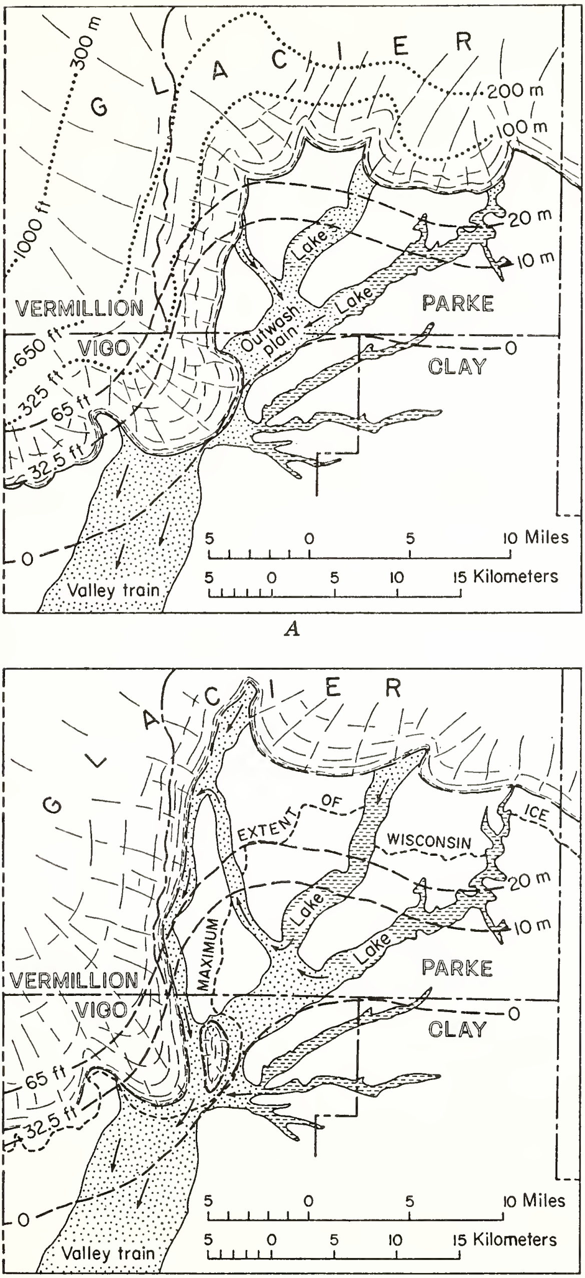

Figure 2. A. Depositional environments in Raccoon Creek area at time of maximum extent of Wisconsin glacier. Dashed contours show extent of crustal depression and dotted contours show estimated thickness of glacial ice.

B. Raccoon Creek area at time of drainage of proglacial lake and reversal of drainage, before isostatic rebound had taken place. Contours show extent of crustal depression.

thickness of the ice. The time required to reach equilibrium depends on the viscosity of materials in the zone of plastic flow, but it probably would be between 10,000 and 100,000 years. In another paper, he (6) suggested that the glacial boundary and the hinge line of subglacial crustal depression should be more or less coincident.

Atherton Island and the lower valley of Raccoon Creek lay within an interlobate re-entrant in the margin of the Wisconsin ice cap (13). It would have been logical for some subglacial depression to have existed beyond the margin of the glacier in such a place. Based on Gutenberg's formula the maximum amount of isostatic adjustment to the weight of the glacier at this place would have been about 100 feet (30 meters), but the ice probably remained in the area only about 1,000 to 2,000 years and melted before equilibrium was reached.

Evidence to support the hypothesis of ice loading depression and isostatic rebound, which has been called on to explain drainage anomalies in Illinois (4) and in Kansas (5), can be found in the present altitudes of terraces underlain by Wisconsin sediments in Raccoon Creek valley and its tributaries. The terrace remnants along the lower gorge of Raccoon Creek between Coxville and the mouth of Leatherwood Creek seem to have no gradient in either direction. If they were to preserve evidence of the southward flow of meltwater that evidently deposited the gravels and sands that underlie them, the surface of the terrace at Mecca should be several feet higher than the terraces at Rosedale, but they have the same altitude. The highest levels of outwash deposition at the junction of Leatherwood Creek and Raccoon Creek at Montezuma are 560 feet in altitude (Site C on fig. 1). The terraces along Raccoon Creek gorge would seem to represent a cut surface. If one allows a gradient of about 3 feet (1 meter) to the mile to the north for such a stream if it were the outlet of a lake, the depression of the north end of Atherton Island would have been 20 to 25 feet (6 to 8 meters) (fig. 2A). Isostatic rebound after the ice had melted would have destroyed the northward gradient of the surface that was cut while the lake drained northward.

Lacustrine sediments normally mark a water plane and should be nearly the same altitude everywhere in a lake. Although a slight variation could be dismissed readily, fossiliferous Wisconsin lake sands and silts along Strangers Branch (Site B on fig. 1), which is more than 8 miles upstream from the southwest end of the lake in Raccoon Creek Valley and only 2 miles from the Wisconsin ice margin in the interlobate re-entrant, lie beneath a terrace that now has an altitude of 600 feet, 60 to 70 feet (20 meters) higher than the dam at the downstream end of the valley. Such a difference in altitude can be explained most easily by sub-ice crustal depression, perhaps also an ice-marginal forebulge, followed by isostatic rebound after the ice had melted from the area.

Overflow waters from the lake in Raccoon Creek valley entered the Wabash by way of the lower outlet to the north, and once a lower outlet had been established, it was maintained even though spasmodic uplift through isostatic rebound was taking place. Dunes, which not only cover the outwash plain between Rosedale and Terre Haute but are found also on the upland farther east, probably were blown from the Wabash Valley during the period when it was the outlet for glacial Lake Maumee. Dunes are abundant on the Maumee Terrace and all higher levels along the entire Wabash Valley. Most of them postdate the diversion and probably were completely incidental to it.

Summary

None of the existing hypotheses for the deflection of Raccoon Creek northward around the east side of Atherton Island in Parke and Vigo Counties, Indiana, have seemed wholly convincing to some geomorphologists. The ease with which loose sand can be eroded makes it seem unlikely that an accumulation of low dunes, as suggested by Bartle, could have been an effective barricade that would block a stream the size of Raccoon Creek. Field data suggest that two other hypotheses, Dryer's ice dam and Tucker's outwash barrier, may partly be valid, but that sub-ice crustal depression may have been of major importance in causing the reversal.

Course-grained sediments (Atherton Formation, Wisconsin Stage) fill the abandoned segment of the valley from Rosedale to Terre Haute. Between Rosedale and Bridgeton the deposits that underlie the terraces change from gravel to sandy silt; few terraces exist upstream from Bridgeton. This distribution of sediments suggests that the fill in the lower part of the valley is a large outwash plain and delta built into a proglacial lake in Raccoon Creek valley when the Wisconsin glacier margin trended in a north-south direction along the west edge of Atherton Island and blocked the mouth of Raccoon Creek north of Terre Haute. The weight of the glacier undoubtedly caused some depression of the surface beneath it, the effects of which should have extended a short distance beyond the ice margin. Altitudes of lake and outwash terraces in Raccoon Creek suggest that the crustal depression there may have been about 60 feet (20 meters), adequate to reverse the drainage as soon as the glacial ice melted from the area.

After the ice had melted far enough westward to open the outlet north of Mecca that was partly filled with outwash gravel, overflow water from the lake swept through the gorge from Coxville northward. Outwash and perhaps stagnant ice blocked the wide valley south of Rosedale. The glacier still covered the west bluffs of the Wabash Valley, and the east side of the valley became an ice-marginal sluiceway. While the gorge served as a spillway for the lake, the overflow waters cut it lower than the channels in the outwash plain southwest of Rosedale. This drainage reversal, once established, continued to exist because postglacial rebound was slow enough to permit erosion to keep pace with uplift. Although this explanation is based on the Wisconsin glaciation, a similar set of events also could have taken place during the Illinoian glaciation and the original diversion might date from that time. The dunes that now cover the outwash plain between Rosedale and Terre Haute probably date from the time the Wabash River served as the outlet for Lake Maumee and are completely incidental to the diversion of Raccoon Creek.

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Flow Diagram for a Computer Program Designed to Calculate Igneous Molecular Norms

John H. Cleveland, Indiana State University

This paper describes one important aspect of a project carried out under the direction of Professor Charles J. Vitaliano by Dr. Richard D. Harvey and the author at Indiana University from 1960 to 1962. The history and theory of ingneous normative mineral computation has been reviewed by Barth (1), and the capabilities and intricacies of its computer programming have been briefly discussed elsewhere (2). The primary purpose of this paper is to present the unpublished flow diagram for this computation in a form adaptable to any electronic digital computer or usable as a guide for manual norm computation instruction.

This flow diagram is the schematic representation of a mathematical sequence of operations that make possible the conversion of the chemical analysis of an igneous rock into the probable quantitative mineral assemblage for that rock. This conversion process, if done manually requires 12 subtractions, 27 additions, 34 multiplications, 39 divisions and 6 comparisons for the computation of just one silica-rich igneous rock. The molecular norm computation was programmed for the computer primarily to avoid the inevitable human error resulting from this tedious process; secondarily to save time if large numbers of norms were required. An experienced person requires in excess of 15 minutes to complete the operation manually (if no mistakes are made) whereas the electronic computer requires about 8 seconds per computation.

The flow diagram (Fig. 1) presented here is nothing more than a series of quasi-mathematical statements connected by lines to show the sequence of operations. The "mathematical language" used here is that used by programmers but readily understandable to the interested geologist with the aid of the following basic rules illustrated by operations shown in figure 1, step 2, and identification of abbreviations, listed in figure 2. Boxed statements are standard mathematical operations that result in the changing of a stored value (such as the cation percentage of calcium oxide) to a reduced value required to account for material used in the formation of calcite; eg: $Ca=Ca-C(O_2)$. Circled statements represent mathematical questions that decide which of two possible steps should now be taken; eg: $Fe^{++}-Ti<0$? (is ferrous oxide minus titanium oxide less than zero?) If the decision is yes, (titanium oxide exceeds ferrous oxide), then the next mineral, ilmenite, must be formed on the basis of available ferrous oxide; if the decision is no, then ilmenite will be formed from titanium oxide. Read in and print out statements are the only other basic statements required for computer operation of this program.

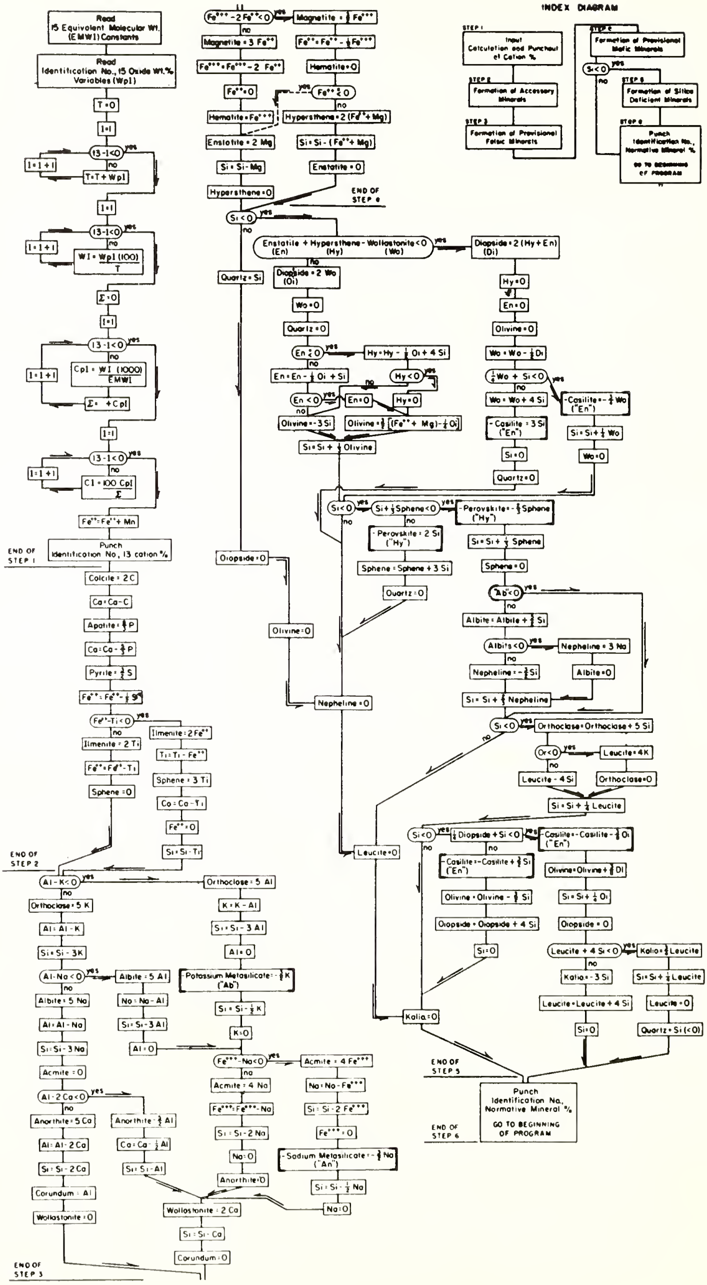
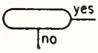


Figure 1. Flow diagram for the computation of the molecular normative mineral assemblage of an igneous rock from oxide percentages obtained by chemical analysis.

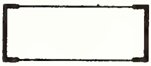
Explanation

Direction of flow; downward if no arrow shown.

Performance of designated operation.



Performance of designated branching operation and flow directions.



Operation involves formation of a silica deficient mineral, designated "X," that is stored in mineral location X as a negative value. Also indicated as

"Ab"	-Potassium Metasilicate ($-K_2SiO_3$)	K	$KO_{1/2}$
Al	$AlO_{3/2}$	Kalio.	Kaliophilite ($KAlSiO_4$)
"An"	-Sodium Metasilicate ($-Na_2SiO_3$)	Mg	MgO
C	CO_2	Mn	MnO
Ca	CaO	Na	$NaO_{1/2}$
CI	Cation % mineral I	Or	Orthoclase ($KAlSiO_8$)
CpI	Cation proportion mineral I	P	$PO_{5/2}$
Di	Diopside ($CaMgSi_2O_6$)	S	Sulphur
EMWI	Equivalent Molecular Wt. Constant I	Si	SiO_2
En	Enstatite, ($MgSiO_3$)	T	Totals
"En"	-Casilite, ($-Ca_2SiO_4$)	Ti	TiO_2
Fe^{++}	FeO	WI	Adjusted wt. % I
Fe^{+++}	$FeO_{3/2}$	Wo	Wollastonite
Hy	Hypersthene $[(Mg, Fe) SiO_3]$	WpI	Chemical analysis wt. % I
"Hy"	-Perovskite ($-CaTiO_3$)	Σ	Sum
I	Index number	0	Zero

Figure 2. Symbols and abbreviations used in the igneous norm flow diagram.

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Manufactural Geography of Harvey, Illinois

Alfred H. Meyer and Marilyn Tschannen, Valparaiso University

Prefatory Profile

This is the eighth study in manufactural geography of Calumet communities of Northwest Indiana-Northeast Illinois, all the preceding ones having been published in the Indiana Academy Proceedings.[1]

Harvey (32,000) is about a score miles from the Chicago Loop, named after T. W. Harvey, an enterprising lumber merchant of Chicago, who in 1890 established the Harvey Land Association, which donated purchased land to the community. Another major incentive for industrial development was the crossing here of three major rail lines, the Illinois Central providing the first transportation in the area and "free transportation for a year to and from Chicago for those who actually settled in Harvey." This railway became the chief locus of modern industry, three-fourths of the major plants being situated along its route. Other prime locative factors, as determined from questionnaire-interview survey, rank in this order: land and/or building availability, market, labor, proximity to regional steel industries. Supplemental considerations include secure plant footings (limestone), adequate city zoning, city tax inducement.

Sixteen industries of over the 100 category employment contacted engage a total of 8,500 employees, who travel to work primarily in automobiles. The newly constructed Tri-State Tollway and projected South Expressway skirting the city on the south and west are expected further to increase the trucking service, an unusually large number of the local plants having already switched from rail to truck for their major transportation requirements.

Fabricating metals, machinery plants and machine shops constitute the chief manufactures, reflective of the raw steel sources as the head of Lake Michigan only 10-20 miles away. Hemmed in virtually by other corporate communities, peripheral industrial expansion is highly restricted (Fig. 1).

The future calls for a more compelling discriminating geographic perspective in appraising industrial site quality than ever before. The

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[1] Those of Greater Blue Island (including Posen, Dixmoor—between Blue Island and Harvey and Alsip—Chicago Heights, Hammond, East Chicago-Whiting, Gary, Michigan City, and LaPorte. As in these instances, the Harvey study is based on questionnaire-interview-field contacts. Industries as treated in this paper—and in the others mentioned—refer only to those of the manufacturing type (not so-called "service" industries). Their generalized classification and distribution pattern are shown in Figure 1. A great miscellany of moldings, forgings, castings, metal work, and machinery products are involved (e.g., railroad, auto, and foundry equipment, internal combustion engines, metal furniture and cabinets, industrial machinery, diversified alloy products, including alloy steel store fronts and doors, automatic gears, etc.).

Gratefully acknowledged in this survey is the cordial and constructive cooperation of Harvey's industrial respondents; of the Executive Director of the Harvey Association of Commerce and Industry, Mr. Ray Nussmeyer; of the City Planning Director, Mr. Frank So; and of the First National Bank of Harvey.

Harvey Association of Commerce and Industry and the City Plan Commission will have to redouble their efforts to "tailor" both internal land availability and external land accessibility to meet the needs of such industries as can be locally accommodated, or refer newcomers to neighboring communities whose geographic situation can be economically integrated into Harvey's own industrial and commercial core.

Geographic Retrospect

Relict strategic site qualities of Harvey date back to Pottawatomie and Pioneer circulation and settlement. As our earlier departmental researches show, the site was wedged in by a primary and a secondary Indian trail-wagon road linking Vincennes with Chicago. The early commercial prominence of this trail-road is reflected in its designation as Hubbard's Trace (see Fig. 1), named after Gurdon E. Hubbard, a famous American Fur Company trader who came into the Chicago area by this route in 1818. An arterial east-west trail crossed the Vincennes trail only two miles to the north, at the southern tip of Glacial "Blue Island." Here also the Little Calumet River on the northeast reverses its course eastward to join the Grand Calumet Lake Michigan bound, while joining westward with the Sag-a-nash-kee Swamp, now essentially the route of the Sag Channel leading to the Illinois River drainage system. Strategically inherent as these water courses may be, their ultimate significance to Harvey and vicinity must await major projections of further Calumet-Sag waterway developments. As in the case of other Calumet communities, it has been railway, then the modern highway that effected the transportation base for manufacturing.

The Illinois Central Railroad provided the initial transportation and incentive for Harvey settlement. A 1700 acre land grant was divided into blocks with large lots priced at $100, "with free transportation to and from Chicago for a year to those who actually become settlers." Next came the Grand Trunk, followed by a third railroad in 1889, part of the present day Baltimore and Ohio Chicago Terminal Railroad system. In the same year, a Chicago lumber merchant, Turlington W. Harvey, purchased substantial amounts of property in the area and formed the Harvey Land Association, to which he gave, in 1890, the land which he had purchased. The village of Harvey officially came into being in 1891.

Under the leadership of Turlington Harvey, the village of Harvey became "The Magic City," growing to a population of 5000 in a three-year period, and adding water and sewer lines, streets and sidewalks, schools and churches, and six industries. These industries were already geared to the southern Lake Michigan steel areas. They manufactured heavy equipment for industries; cold rolled shafting; railroad supplies; and road-grading machinery.

Electric lights and a street car line were added to the village by 1893, when the World's Fair (Columbian Exposition) was held in Hyde Park near the Illinois Central Railroad. The Harvey Land Association used the proximity of this gathering of people to promote Harvey as a prime spot for industrial development. One of those attracted by Harvey was J. H. Whiting, who founded the Whiting Corporation, now Harvey's third largest industry, in 1894. The firm manufactured cupola furnaces

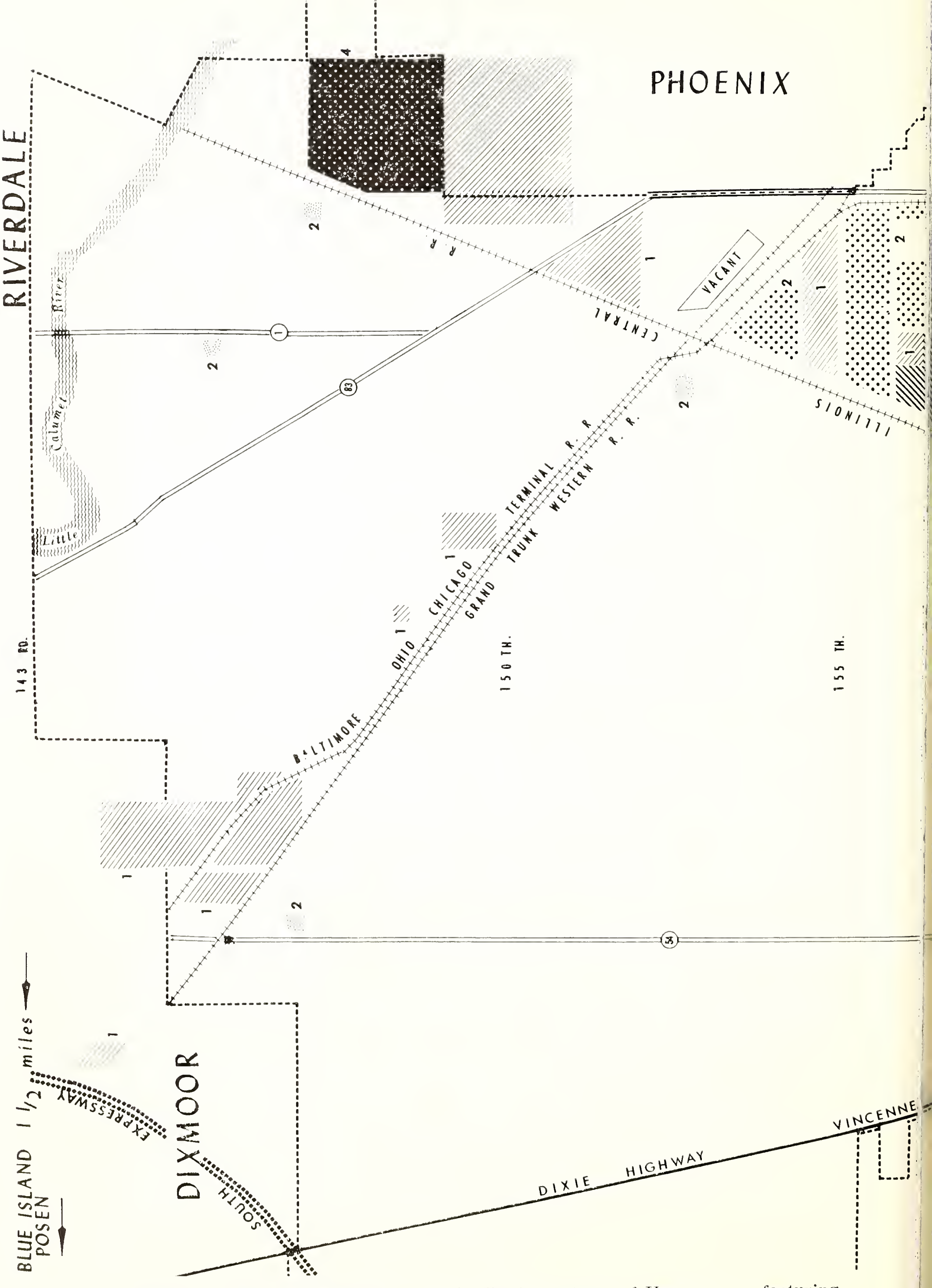
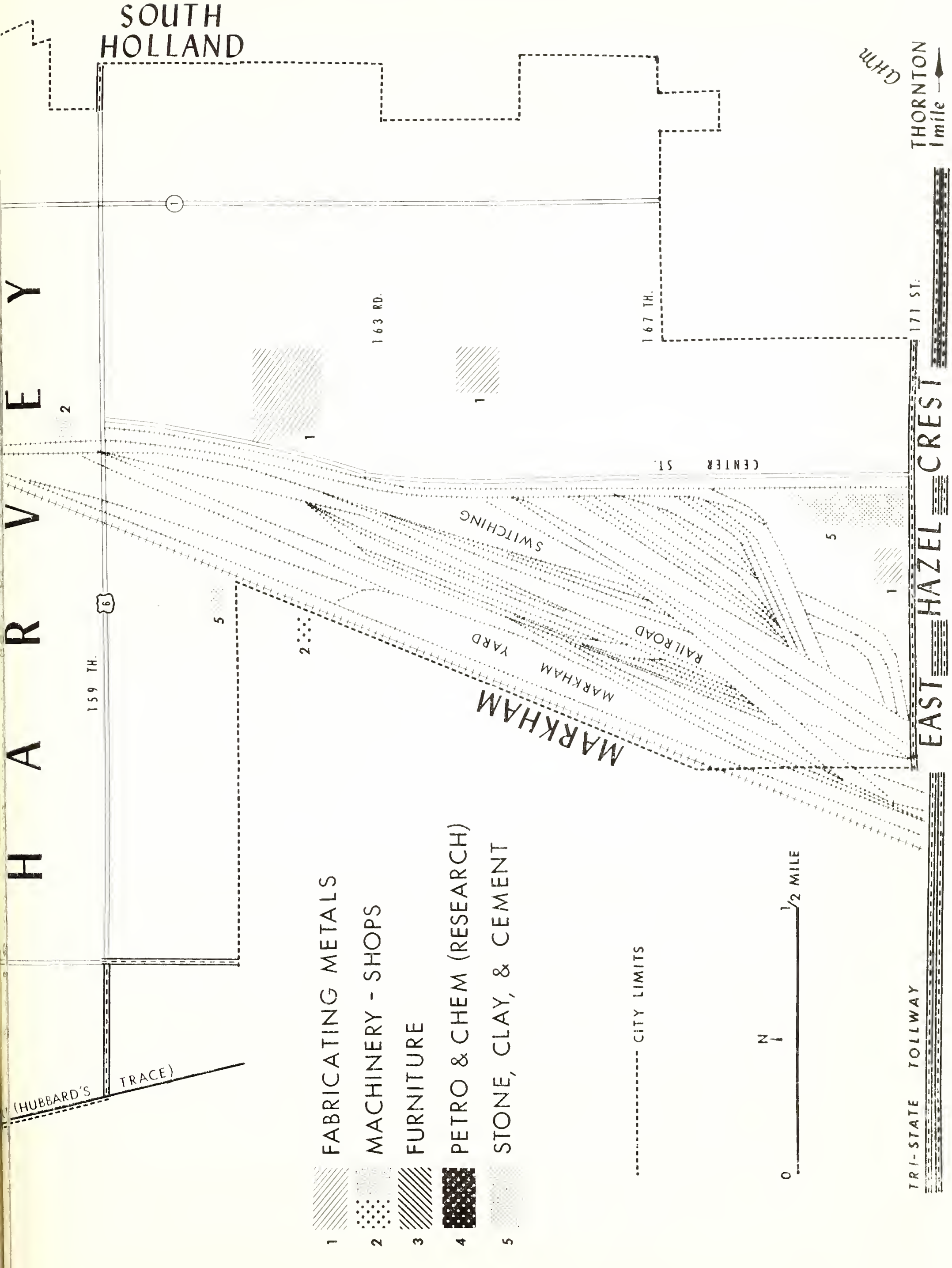


Figure 1. Basic classification and distribution pattern of Harvey manufacturing reflects close geographic coherence to the original railway system.


SOUTH HOLLAND
HARVEY
MARKHAM
EAST HAZEL CREST
THORNTON 1 mile →
159 TH.
163 RD.
167 TH.
171 ST.
CENTER ST.
MARKHAM SWITCHING YARD
MARKHAM RAILROAD
(HUBBARD'S TRACE)
TRI-STATE TOLLWAY
1
6
1
2
5
1 FABRICATING METALS
2 MACHINERY - SHOPS
3 FURNITURE
4 PETRO & CHEM (RESEARCH)
5 STONE, CLAY, & CEMENT
CITY LIMITS
N
0
1/2 MILE
GHM

in the beginning, and expanded production to include other types of industrial equipment. Eighty per cent of the gray iron melted in the United States today is melted in Whiting cupolas.

A brief abstract of established and disestablished industrial plants of Harvey, as reported in greater detail in "The City of Harvey" by the First National Bank, will serve as a representative profile of how Calumet industrial geography is affected by time and circumstance. The Bellaire Stamping Works burned in 1900 and was relocated in Terre Haute, Indiana. The Ingall-Shepard Division of the Wyman-Gordon Company was built on its site between lines of the B&O and Grand Trunk Railroads (Fig. 1) in 1910, manufacturing forgings and crankshafts. The Woods-Mobilette automobile firm had a peak production of 1000 cars a month in 1914. The Austin Manufacturing Company merged with an Aurora company in 1939 and moved out of Harvey. The William E. Dee Company ceased its foundry operations and is today restricted to the sale of sewer tile and kindred products. The American Stove Company, moved to Harvey in 1897 and was a large and successful firm, employing over 600 workers at its plant on Commercial Avenue near 157th Street and making many innovations in the cooking stove industry. The firm moved to St. Louis in 1948. The Fahralloy Company expanded and moved to Harvey in 1937, taking the site of the old Koch Machine Shop. Maremont Automotive Company came to Harvey in 1939 and has expanded considerably, now employing over 800 people.

Locative Factors

A major concern in a geographic study of this type is "relative" location—location relative to the chief anchor items of man's establishments. The senior author, throughout the eight industrial Calumet studies now completed, has found no more reliable basis for plant location "determinants" than the statements made by the industrialists themselves. Questionnaires and interviews thus provided detailed information on sixteen major industries in Harvey. Most industrialists listed several factors as reasons for locating in Harvey, predominantly in the approximate order given:

1. Transportation—Half of the industries considered this to be of major importance. Five of them mentioned railroads as the prime transportational attractor: good transportation; served by three different railroads; accessibility to the Illinois Central; three railroads adjacent to company property.

2. Land and/or Building Available—Nearly half emphasized space: building available and could move in immediately; land was available; only building available; space was needed and the building was there.

3. Market—Six firms reported Chicago and Midwestern market as a consideration: new market in the middle Midwest; close to market; Chicago principal market.

4. Labor—Over a third focused on labor: good labor supply; skilled labor nearby; abundant labor.

5. Proximity to steel industries—The availability of raw materials, especially steel, was mentioned by one-fourth of the manufacturers: close to the Gary Steel Mills; raw materials near; proximity to steel mills.

6. Miscellaneous considerations cited: ground under plant was limestone; near owner's home; family residences, city zoning; room for expansion; tax inducement from city.

But, as the study of Harvey and of other industrial Calumet communities reveals, spatial and other environmental factors involve varying values as related to advancing technology and time. A community may thus also lose a most enterprising establishment, as is illustrated in the case of the Perfection Gear Co. This company came to Harvey in 1933. It has no branch plants, and employs 450 people from Harvey and surrounding towns. It was noted that abundant labor supply, an earlier attractive feature for locating its plant in Harvey, is now tight; competition for it is great. Other factors: present plant now obsolete, haphazard series of additions, lack of adequate storage space. The management has decided to move to the South—Darlington, South Carolina—to avail itself of cheaper labor.

Regional removals may at times evoke local resentment at government "discriminatory" practices of aiding some regions in getting industries at the expense of other regions.

Transit Transition from Train to Truck

Harvey developed as an industrial center because of its railroads. Note in Figure 1 the alignment of the major plants along the railways, with particular attraction to the Illinois Central, and the junction of this railway with the other two—the Baltimore and Ohio and the Grand Trunk. Now, however, the use of the railroads by the industries has declined. Nearly a third of the industrialists contacted in this study indicated that they had switched from rail to truck transport in the last ten years. Almost half of the industries now use trucking as their exclusive means of transportation, both for receiving raw materials and for shipping the finished product.

Truck transportation has increased because the truck is more adaptable, no rail sidings are needed at either the origin or the destination; trucking is cheaper, especially for small shipments; and deliveries often faster; some customers request delivery by truck.

New road developments will probably help Harvey industry to improve its transportation patterns. The Tri-State Tollway on the southern periphery leads to major markets in the Midwest. Route 80 through Hazelcrest (Moline Expressway) is being developed. The proposed leg (South Expressway) of the Dan Ryan leading to Chicago skirts northwest Harvey. The regional expressway pattern and Harvey neighborhood interchanges are shown in Figure 2. The vacant land south of Harvey near Thornton was considered for the location of a large truck terminal, but it was decided that this would take too much land for the number of people it would employ.

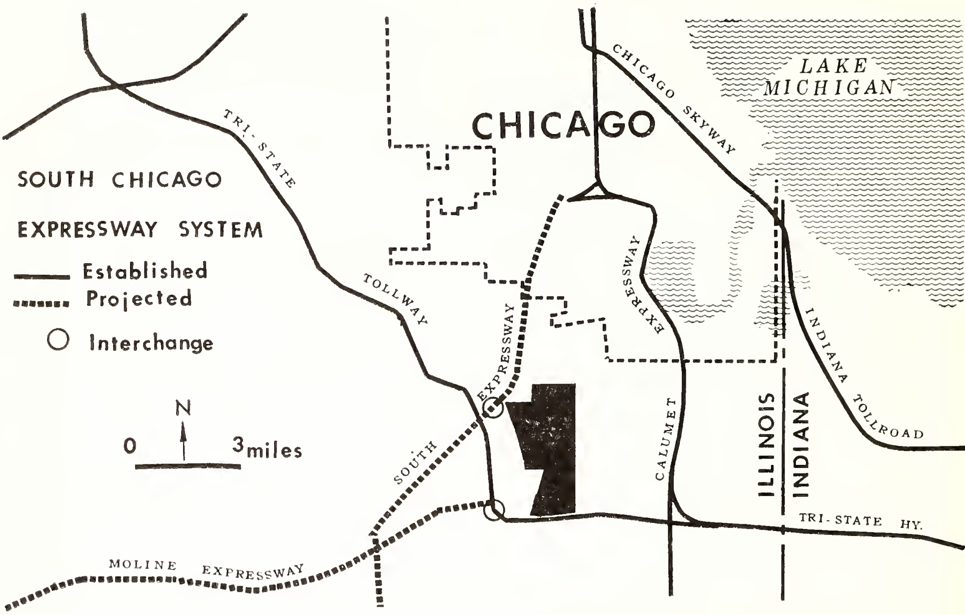


Figure 2. Existing and projected metropolitan expressway system related to Harvey's regional position in the South Chicago region presages an extension of truck transit to Midwestern and other more distant markets. (Adapted from map of State of Illinois Department of Public Works and Buildings.)

Proximity of Raw Materials, Labor, and Midwest Market of Major Regional Concern

The major raw material used by Harvey industry is steel, which comes from the Gary steel mills in nearly half of the cases surveyed. Other steel comes from the Chicago area mills, Indiana Harbor and East Chicago. One industry noted that there was a shipping cost ½¢ higher per pound for steel from Pittsburgh. Wood and packing materials are supplied by Chicago distributors. Limited raw materials from other parts of the United States include aluminum, chemicals, nickel, and brass. Canada, France, Belgium, and Sweden were listed by one firm for importation of products to be processed or assembled.

The sixteen industries interviewed employed 8,386 people, mostly from Harvey and the surrounding communities, embracing the entire south Cook County area.

Employees travel to work predominantly in automobiles; some use the Suburban Safeway Bus Line; a few use the Illinois Central Railroad commuter service; and several walk from their homes nearby. There is no housing problem for workers, since both Harvey and the surrounding residential communities have plenty of homes available.

All industries employing over a hundred people were contacted in this study. Five of them each employ over 500 people.

All Harvey firms contacted in this study had markets in the Midwest. Nine of the sixteen firms had completely Midwestern markets. One mentioned that with the increase of population, his firm had shifted from a market in the East and Midwest to a solely Midwestern market. Significant contributory factors include the sizeable population in the Midwest, the location of competitive manufacturers in other parts of the country, and the establishment of branch plants of Harvey industries in other areas.

Industry-Community Interrelations

Community attitudes favoring industry is strongly reflected in the activities of the Chamber of Commerce and Industry. This tailors situations for the various industries interested in locating in Harvey. Available land is classified by size and described by maps and documents from the office of the Executive Director.

Most of the industries considered the zoning and planning of Harvey to be adequate for their needs, although several mentioned that the residentially-zoned land near their sites preclude expansion. Price of land and taxes were also cited as a factor discouraging expansion of industry. Complaints about planning centered on truck transportation now used by the majority of the industries. The pavements could be improved and traffic lights installed to facilitate the trucking.

Utilities have been planned well since the establishment of Harvey and there were few complaints about the water, electricity, or sewerage supplied by the city. Several companies have their own electrical generators for emergency purposes, but the reliability of the Harvey public service company was described as good. The industrial uses of water are washing, cooling, steam, settling, and sanitary. All industries gave a favorable rating on quality of water and reliability of Harvey's water system.

Reciprocally, the industries generally make substantial contributions to community welfare, such as sponsoring local fund drives, supporting hospital and Y.M.C.A. programs, and providing films and speakers to local groups.

Assessing Harvey's Future Manufactural Viability

The West Calumet region, of which Harvey is a vital part, once experienced an industrial boost from migrants from the East. It is now faced with the prospect of losing manufactural units to the South and even to the West, for much the same geographic circmstances that once created the shift from the East to the Midwest—more and cheaper space, more and cheaper labor, closer raw materials and more distant expanding markets, augmented motor transport facilities.

And just as Chicago industries once explored for expansible sites in suburbia, like Blue Island and Harvey, now these communities in turn experience space saturation problems, with severe industrial site restrictions. Peripheral population pressure is reflected in the half-dozen corporate communities that almost fence in the city of Harvey (Fig. 1). And urban annexations elsewhere of county land become increasingly more complicated. Witness, for example, the four-score-sided polygon of Harvey.

Comparing the manufacturing pattern of the Zoning Map (Fig. 3) with the actual manufactural occupance pattern (Fig. 1) raises some questions also significantly related to appraisal of the future industrial potential of Harvey. Each map in a sense connotes a different picture. Figure 1 suggests by its rail-aligned plant sites severely restricted premises for plant occupance. Figure 2, on the other hand, indicates dispersed and expansive planned plant sites not now occupied by manufacturing. A check with the Director of Planning and with the Executive Director of the Association of Commerce and Industry resolves not only the apparent geographic discrepancy, but also illuminates vagaries between potential and actual development a community may expect to encounter and which geographic mapping exposes but does not in itself resolve. Mr. Nussmeyer, for example, reports an annexation problem: Several owners of property near the B&O "will not annex to the City of Harvey unless the whole parcel is sold." References to three sizeable tracts zoned for general manufacturing will illustrate other problems involved in realizing the full geographic manufacturing potential of an area.

1. The segment bounded by the I.C. R.R., the B&O R.R. 152 Street, and the City Limits: Occupying this area are

> "a small building that has been used for a grocer's warehouse, but which will soon be getting a new tenant; a building used to house part of the operations of a scrap dealer; some large abandoned grain silos that sit on land that has not exchanged hands for forty years, and for which the title is somewhat cloudy since the present owner cannot be located; and, finally, a building just to the east of the I.C. tracks that has recently been remodeled by an industrial developer, but still lacking a tenant. When the various buildings that I have mentioned are subtracted from the tract in question, we are left with a piece of land that might house one industry that employs a couple hundred workers at the most if parking, storage, and expansion room are also taken into account. I wish I could give you the asking price of the remaining portion but I do not know it. However, it is generally known that it is quite expensive when potential buyers compare it to farm land on the outskirts of the metropolitan area. It should be remembered that this portion of the City was a part of Harvey since incorporation seventy-five years ago."

2. Another parcel zoned for general manufacturing is mostly occupied by railroad switch tracks (the Markham Yard, between I.C. R.R. and Center Street, Fig. 1). This is largely owned by the I.C. Railroad, and in part by investment company or residents who at this time do not wish to sell. This area would almost double manufactural acreage, besides providing sites of high quality, were it made available for industry, but no information is at hand at the moment as to any contemplated change of this land use.

3. A third section, between 167th and 171st, and east of Center Street to the City Limits is vacant at present except for a warehouse. This section together with some others command a high price as compared with agricultural land values, and thus serves as a deterrent to immediate occupance. City officials concerned with this differential land cost problem are disconcerted by the fact, then, that Harvey in competition with other communities for new industries can offer only land that is priced substantially higher than that farther out. Right now, two local major industries contemplate removal as a result of price of local sites being substantially higher than other land being investigated elsewhere, despite the availability of land of sufficient size within the present city limits and just outside to the southeast, and despite the official pleadings to hold these industries. One is headed for North Carolina with its substantially different "economic climate," and the other moving to Matteson, only eight miles south of Harvey, which meets their site requirements for expansion.

The relation of initial higher costs of land within Harvey as compared with those of outlying tracts of land must be viewed in the overall perspective of geographic quality of manufacturing sites. As Mr. So, the Planning Director observes, that while "speculation" is reflected in part in the price boost, the higher price also does reflect that Harvey's industrial sites already are served or can be served very quickly by a whole host of municipal services. Illusory experiences may be in store for plants locating in new areas whose initial price level does not reflect the ultimate cost of "improved" facilities. As Mr. So points out: "Eventually someone has to pay for the sewers, water, police and fire protection, schools, and other services. Some industries are already finding this out in the Chicago Metropolitan area. I think that we shall experience additional industrial development when industries are capable of paying higher prices and those that are perhaps more aware of the eventual costs look into the relative advantages of locating in Harvey."

Observations and operations of Harvey's Association of Commerce and Industry noteworthily supply further insights on future projections as related to the present and past experiences.

Dialogue between Interviewer and Interviewee

(Mr. Ray Nussmeyer, Executive Director of Harvey
Association of Commerce and Industry)

Q. Are you in a key position to make evaluation of industries in the area?

A. We have an industrial development committee which not only seeks out new industries, but also tries to keep our finger on the pulse of the industries of the area, and their economic needs.

Q. We have mapped Harvey plants and found space pretty much staturated with industry. Is this correct?

A. Well, it was true of Harvey. Last year we were able to locate two light industries in what was county property, since annexed to the City. . . . These 160-180 acres we can now use, primarily for light industry, because in no case do we have one large tract. . . . Basically 20 acres are left in the city limits.

Q. At what point do you decide to incorporate areas on which there are industrial sites, rather than leave them outside of the city limits?

A. I'm afraid that this is not our choice. In fact, the property owners would find it more expensive to be annexed to a city than to be in the county unless the property is actually sold for industrial purposes . . . . normally won't bring it in and have it put on the tax rolls just for speculation. In 1959, there was a comprehensive plan suggested for setting aside of industrial land that was never adopted, but it was county land and the property holders have not chosen to come into the city.

Q. Are there cases where industries prefer to stay outside the city?

A. We have not found it so because of water, fire protection, etc., supplied by the city. We have a fire rate of five, which is fairly good . . . . in county it would probably be eight or nine, so it would pay for the taxes.

Q. When the geographer makes an industrial study, he generally thinks in terms of including peripheral community sites. Where would you place the limits of the so-called Harvey industrial area?

A. We don't delimit much beyond the city limits, primarily because we have communities on all four sides.

Q. Is there anything in Riverdale to the northeast, Phoenix to the east, East Hazelcrest to the south, and Posen to the northwest, that would be included in your thinking about future industrial planning for your Harvey area?

A. We would first show an industrial prospect an area in Harvey, and if none were suited, take them as far as Lansing, the thought being that money spent within that radius is an economic value to Harvey also. . . . When we're talking to an industrial prospect, who probably would prefer to live in a $45-50,000 home, for executives, our tour of the area would include Homewood and Flossmoor and Olympia Fields. . . . It would also include the golf courses in that area . . . the airport towards Hammond, usable for privately-owned aircraft.

Q. Does your Chamber provide literature explanatory of these various things?

A. Not necessarily, because we're in a rather fortunate geographical location. . . . Our major job is a "tailoring" situation. We get enough people in the office who say, "We would like twenty acres, we have twenty executives, we need forty unskilled laborers," and then we tailor a program to them.

Q. And you still find adequate facilities generally within the present corporate limits to do this?

A. As stated, last year we were fortunate in getting two light industries, and considering that the normal average is to get one out of 150 prospects, we didn't have to go near that high to get the two.

Q. In other words, your prospects are good. What would you say are your limitations to get prospects to settle here?

A. Land only. . . . Some acreage, but not big scale.

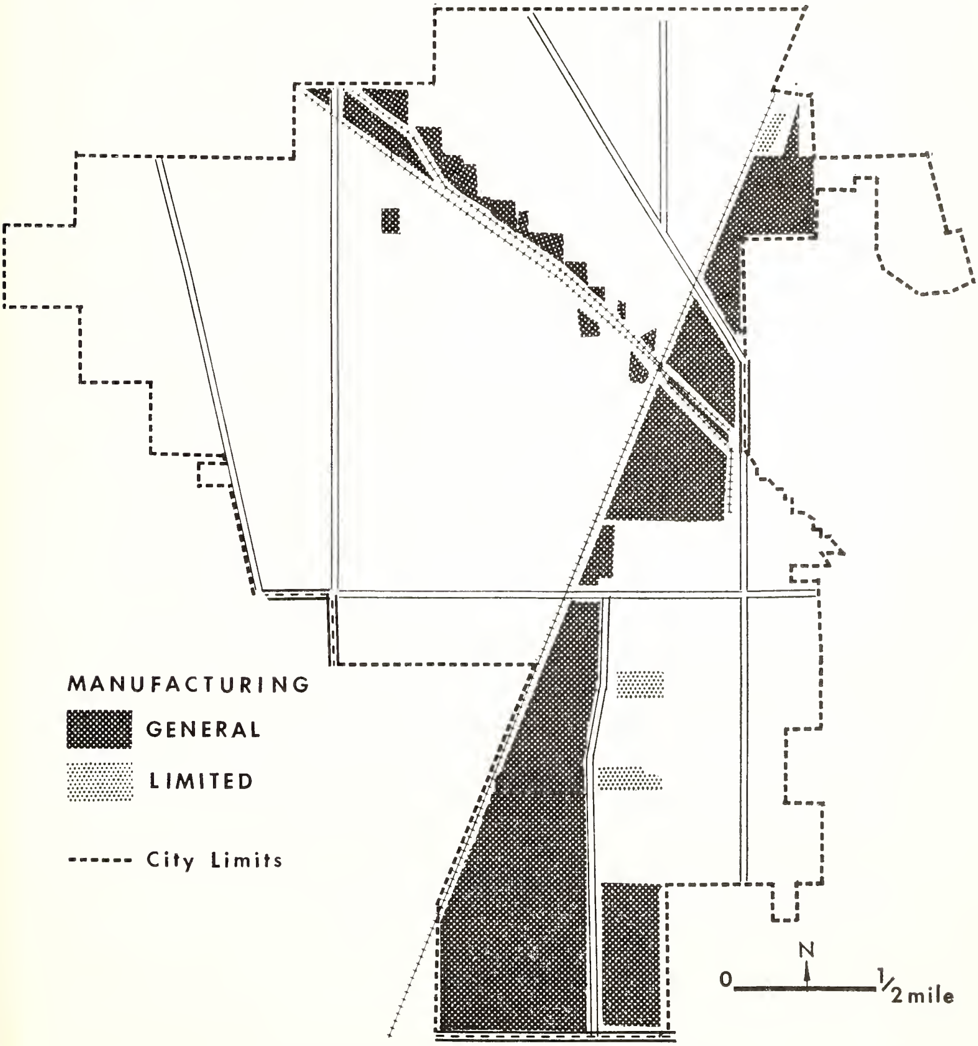


Figure 3. Zoning of manufactural districts of Harvey correlates closely with the major transportation pattern. Sites for limited manufacturing (on small acreages) may be expected to increase, but adjoining urban areas locally restrict corporate extensions for large industries, as shown in Figure 1. (Adapted from Harvey's City Zoning Map.)

The above dialogue, then, together with preceding cartographic and textual portrayal of Harvey's industrial pattern and processes of development, predicates primarily limited expansion potential of limited manufacturing within the present city limits. There are now only three such sites (see Fig. 3). The Greater Harvey area involves some developable sites such as to the southeast where Thornton now has only the major rock quarry. The newly established and projected expressway system in the area (Fig. 2) presages industrial promotional possibilities.

The ultimate appropriation values of these several site and circulation dimensions to the future of Harvey and vicinity must await the new planning program of the city. Harvey has recently added a Department of Planning and Development to the previously existing City Plan Commission, headed by a director and chairman respectively. The Director is a professionally trained planner, employed full-time, who has access to the latest media of industrial site checkups (e.g., large scale Sanborn atlas, and commercial air photos). A comprehensive and coordinated plan for the development of the city has been designed and federal appropriation (701) sought for implementation of the program, estimated at an approximate cost of $103,000. The plan involves consideration of the future growth pattern of Harvey in terms of density and pattern of land use, including, of course, those concerned with industrial development.

Zipf's Rank-Size Theory Applied to Some Cities in Indiana and the Ohio River Watershed

Thomas Frank Barton, Indiana University

According to Mayer and Kohn in **Readings in Urban Geography** (the most widely used Urban Geography text in the United States), G. K. Zipf's rank-size theory may be stated as follows:

> ". . . that the towns of a country are arranged according to size, the *N*th town having 1/*N*th the population of the first."(1)

Since the writer believes in presenting concepts, theories, principles and other major ideas in the framework of the state and large watershed where an Urban Geography class is held, in this article Zipf's rank-size theory will be applied to: (1) 23 cities in Indiana with populations of over 20,000, (2) eight standard metropolitan statistical areas located in or partially in Indiana, (3) 24 cities in the Ohio River watershed with over 50,000 and (4) 15 cities in the Ohio River valley with populations over 30,000.[2]

The number of cities in each geographic area to which the theory was applied was selected somewhat arbitrarily. The writer believes this selection to be as scientific if not more so than the attempt to apply the theory. Some discretion was used. Since the number of standard metropolitan statistical areas is small the theory was applied to all eight. Indiana cities with populations of less than 20,000 and Ohio River valley cities with less than 30,000 were not used because fewer cities below these sizes have active, progressive city planning commissions which might use Zipf's rank-size theory as a technique if it were to be proven useful. The application of the theory in the Ohio River watershed was cut off when cities of less than 50,000 were reached because it was obvious that for practical purposes there wasn't sufficient correlation to continue.

Twenty-three Cities in Indiana

According to the 1960 United States census, there are 23 cities in Indiana with populations of 20,000 or more. These statistics give the population of the political cities and do not include the people living in the geographic or agglomerated city outside the precisely drawn legal boundaries.

In Table 1 data about these 23 cities are presented in six columns. In the first the 23 are listed in descending order of size, with their 1960 populations in the second column. The fractions of Zipf's rank-size theory are placed in the third.

In the fourth appears the number of people who should be living in the city if Zipf's theoretical sizes existed in reality. For example, Gary, as the second largest city in Indiana, according to Zipf's theory should have a population of ½ of that of Indianapolis, or 238,129. However, in 1960, Gary had only 178,312 inhabitants, or 59,817 less. These variations from the theoretical size are listed in the fifth column. The — sign indicates fewer people and the + sign more.

TABLE 1

Twenty-three Cities in Indiana

	City	1960 Population	Zipf's Rank Size Fractions	Zipf's Theoretical Size	Variation in Population	Percent Variation
1.	Indianapolis	476,258				
2.	Gary	178,312	1/2	238,129	— 59,817	—25.1
3.	Fort Wayne	161,776	1/3	158,753	+ 3,023	+01.9
4.	Evansville	141,531	1/4	119,065	+ 22,466	+18.8
5.	South Bend	132,445	1/5	95,252	+ 37,193	+39.0
6.	Hammond	111,698	1/6	79,376	+ 32,322	+40.7
7.	Terre Haute	72,500	1/7	68,037	+ 4,463	+06.6
8.	Muncie	68,603	1/8	59,532	+ 9,071	+15.2
9.	East Chicago	57,669	1/9	52,918	+ 4,751	+08.9
10.	Anderson	49,061	1/10	47,626	+ 1,435	+03.0
11.	Kokomo	47,197	1/11	43,296	+ 3,901	+09.0
12.	Richmond	44,149	1/12	39,688	+ 4,461	+11.2
13.	Lafayette	42,330	1/13	36,635	+ 5,695	+15.5
14.	Elkhart	40,274	1/14	34,018	+ 6,256	+18.4
15.	Marion	37,854	1/15	31,751	+ 6,103	+19.2
16.	New Albany	37,812	1/16	29,766	+ 8,046	+27.0
17.	Michigan City	36,653	1/17	28,015	+ 8,638	+30.8
18.	Mishawaka	33,361	1/18	26,459	+ 6,902	+26.1
19.	Bloomington	31,358	1/19	25,066	+ 6,292	+25.1
20.	Laporte	21,157	1/20	23,813	— 2,654	—11.1
21.	Logansport	21,106	1/21	22,679	— 1,573	—06.9
22.	Columbus	20,778	1/22	21,648	— 970	—04.0
23.	New Castle	20,349	1/23	20,707	— 358	—01.7

In the sixth column the variation of the actual number from the theoretical is indicated in percentages.

No higher mathematics than arithmetic is used in this presentation because the writer does not wish to limit the number of potential readers.

A brief study of the statistics in Table 1 reveals the following generalizations about Indiana's 23 largest cities:

1. The range of variation is from a minus 25.1 per cent (in the case of Gary, the second largest city) to a plus 40.7 percent (in the case of Hammond, the sixth largest) resulting in a total variation of 65.8 percent.

2. The 23rd largest city, New Castle, comes the nearest to having the same population as the theory would indicate. New Castle's actual size is only a minus 1.7 percent smaller. Fort Wayne, the third largest city, is only 1.9 percent larger.

3. In seven cities the percentage of variation is greater than 25 and in seven others it is less than ten. The latter seven cities rank in 3rd, 7th, 9th, 10th, 21st, 22nd and 23rd positions in descending order of size.

4. The 1960 population census of the 23 largest cities in Indiana do not support Zipf's rank-size theory. Consequently, city planners in Indiana could not rely on applying Zipf's theory as a practical technique.

5. The observation and generalization that Mark Jefferson made over a quarter of a century ago that many countries (political areas) have one large city which is two or three times numerically greater than the second is substantiated by Indianapolis' being in 1960 approximately three (2.67) times larger than Gary, the second largest.

Because of insufficient correlation between the actual population sizes of these cities and their theoretical sizes, a map was not made to show the distribution of Indiana's 23 largest political cities.

Standard Metropolitan Statistical Areas

The same method used in examining the 23 largest cities in Indiana was applied to the eight standard metropolitan statistical areas in or partially in the state. A brief study of the data in Table 2 reveals the following generalizations:

TABLE 2

Standard Metropolitan Statistical Areas in Indiana

City	1960 Population	Zipf's Rank Size Fractions	Zipf's Theoretical Size	Variation in Population	Percent Variation
1. Indianapolis	697,567				
2. Gary-Hammond-East Chicago	573,548	1/2	348,784	+224,764	+64.4
3. South Bend	238,614	1/3	232,522	+ 6,092	+ 2.6
4. Fort Wayne	232,196	1/4	174,392	+ 57,804	+33.1
5. *Evansville	165,794	1/5	139,513	+ 26,281	+18.8
6. *Louisville	114,192	1/6	116,261	— 2,069	— 1.8
7. Muncie	110,938	1/7	99,652	+ 11,286	+11.3
8. Terre Haute	108,458	1/8	87,196	+ 21,262	+24.4

* The statistics given in the second column after Evansville and Louisville refer to the population in the counties of Indiana which are a part of the Evansville and Louisville Standard Metropolitan Statistical Areas.

1. The range of variation is from a negative 1.8 percent to a positive 64.4 percent resulting in a total of 66.2 percent. This range is similar to the total range when the theory is applied to Indiana's 23 cities but the variation is more on the positive side.

2. The sixth largest standard metropolitan statistical area of Louisville is only 1.8 percent smaller than the theory indicates its size should be. And the standard metropolitan statistical area of South Bend is only 2.6 percent larger.

3. In sharp contrast with the small percent variation between the actual and the theoretical sizes of the Louisville and South Bend standard metropolitan statistical areas are those of (1) Gary-Hammond-East Chicago which is approximately two-thirds larger than it should be and (2) Fort Wayne, about a third larger.

4. The 1960 populations of these eight standard metropolitan statistical areas do not support Zipf's theory.

The Ohio River Watershed

Although Zipf's theory in Urban Geography has been applied to political units, the writer applied the theory to the 24 largest cities in the Ohio River watershed which had populations of over 50,000 in 1960. Most of Indiana's territory is in the Ohio River watershed.

Data in Table 3 substantiates the following generalizations:

1. Thirteen of these 24 cities have over 90 percent more people than they should have (column 5 of Table 3). Or, one may say that these 13 cities are almost twice as large as they should be.

TABLE 3

Cities in Ohio River Watershed over 50,000

City	1960 Population	Zipf's Rank Size Fractions	Zipf's Theoretical Size	Variation in Population	Percent Variation
1. Pittsburgh, Penn.	604,332				
2. Cincinnati, Ohio	502,550	1/2	302,166	+200,384	+66.3
3. Indianapolis, Ind.	476,258	1/3	201,444	+274,814	+73.3
4. Columbus, Ohio	471,316	1/4	151,083	+320,233	+47.2
5. Louisville, Ky.	390,639	1/5	120,866	+269,773	+44.8
6. Dayton, Ohio	262,332	1/6	100,722	+161,610	+62.3
7. Nashville, Tenn.	170,874	1/7	86,333	+ 84,541	+97.9
8. Youngstown, Ohio	166,689	1/8	75,542	+ 91,147	+82.9
9. Evansville, Ind.	141,543	1/9	67,148	+ 74,395	+90.2
10. Chattanooga, Tenn.	130,009	1/10	60,433	+ 69,576	+86.9
11. Canton, Ohio	113,631	1/11	54,939	+ 58,692	+93.6
12. Knoxville, Tenn.	111,827	1/12	50,361	+ 61,466	+81.9
13. Charlestown, W. Va.	85,796	1/13	46,487	+ 39,309	+84.5
14. Huntington, W. Va.	83,627	1/14	43,167	+ 40,450	+93.7
15. Springfield, Ohio	82,723	1/15	40,289	+ 42,434	+94.9
16. Terre Haute, Ind.	72,500	1/16	37,771	+ 34,729	+91.9
17. Hamilton, Ohio	72,354	1/17	35,549	+ 36,805	+96.6
18. Muncie, Ind.	68,603	1/18	33,574	+ 35,029	+95.8
19. Lexington, Ky.	62,810	1/19	31,807	+ 31,003	+97.5
20. Covington, Ky.	60,376	1/20	30,217	+ 30,159	+99.8
21. Warren, Ohio	59,648	1/21	28,778	+ 30,870	+93.2
22. Kettering, Ohio	54,462	1/22	27,470	+ 26,992	+98.3
23. Johnstown, Penn.	53,949	1/23	26,275	+ 27,674	+94.9
24. Wheeling, W. Va.	53,400	1/24	25,181	+ 28,219	+89.2

2. Another five cities are over 80 percent larger.

3. Twenty-two of the 24 cities are over 60 percent larger.

Ohio River Valley

The statistics in Table 4 concerning the 15 cities in the Ohio valley with populations of over 30,000 substantiate the following generalizations:

1. The range is from a minus 40.7 percent to a plus 93.9 percent resulting in a total of 134.6.

2. Thirteen of the 15 cities are smaller than the theory would indicate. Nine of these are over 30 percent smaller.

TABLE 4

Cities Along the Ohio River

City	1960 Population	Zipf's Rank Size Fractions	Zipf's Theoretical Size	Variation in Population	Percent Variation
1. Pittsburgh, Penn.	604,332				
2. Cincinnati, Ohio	502,550	1/2	302,166	+200,384	+66.3
3. Louisville, Ky.	390,639	1/3	201,444	+189,195	+93.9
4. Evansville, Ind.	141,543	1/4	151,083	— 9,540	— 6.3
5. Huntington, W. Va.	83,627	1/5	120,866	— 37,239	—30.8
6. Covington, Ky.	60,376	1/6	100,722	— 40,346	—40.1
7. Wheeling, W. Va.	53,400	1/7	86,333	— 32,933	—38.1
8. Parkersburg, W. Va.	44,797	1/8	75,542	— 30,745	—40.7
9. Owensboro, Ky.	42,471	1/9	67,148	— 24,677	—36.8
10. New Albany, Ind.	37,812	1/10	60,433	— 22,621	—37.4
11. Paducah, Ky.	34,479	1/11	54,939	— 20,460	—37.2
12. Portsmouth, Ohio	33,637	1/12	50,361	— 16,724	—33.2
13. Steubenville, Ohio	32,495	1/13	46,487	— 13,992	—30.1
14. Ashland, Ky.	31,283	1/14	43,167	— 11,884	—27.5
15. Newport, Ky.	30,070	1/15	40,289	— 10,219	—25.4

3. The only close correlation between actuality and the theory is Evansville, the fourth largest city in the valley, which has a minus variation of 6.3 percent.

Falacies of Applying Zipf's Theory

There are at least two major falacies in applying Zipf's theory to any political or geographic area in the United States. First, the United States census gives only the population of the political city. And often, if not usually so, the geographic or "agglomerated"[3] city is much larger than the political one in both areal size and population. Many cities have not expanded their political boundaries regularly so as to include all the urban population. If all the people clustered in a settlement are not recorded, is it not foolish and scientifically unsound to attempt to compare the population of these settlements or cities and apply Zipf's theory or other theories?

Over 30 years ago before this theory received wide attention in America's Urban Geography field, many geographers in the United States abandoned the practice of attempting to compare the sizes of cities or to characterize the growth of an individual or a group of cities because different methods and rates of annexation resulted in statistics that did not warrant comparisons.

Second, not only is there no uniform method of computing all of the people living in a cluster settlement or geographic city, but because of the proliferation of political units around large cities (such as independent legally-established villages, towns and cities), the population in a cluster settlement is often fragmented and listed in the census under different names. This is especially true of the largest settlements. For example, the number of people living in the cluster settlement of

Indianapolis in 1960 was much larger than that of the political city for the same year. The surface area of some political cities is completely surrounded by political boundaries of other legal settlements.

In Conclusion

1. Zipf's theory is not substantiated by an examination of: (1) the 23 largest cities in Indiana, (2) the eight standard metropolitan statistical areas, (3) the 24 largest cities in the Ohio River watershed or (4) the 15 largest in the Ohio River valley.

2. However the generalizations based on the data in the four tables do not necessarily discredit Zipf's theory because is not his theory based on the assumption that all the people clustered in a single settlement are recorded?

3. Because of the method of collecting census statistics and the political fragmentation of single cluster settlements, Zipf's theory has a limited or very little value in functional planning in the large cities in Indiana and the Ohio River watershed.

4. By applying Zipf's theory to a group of cities and supplying the type of data presented in the tables of this article one provides a good teaching technique because it stimulates class discussion and the students speculate about the findings.

5. The writer believes that geographers and others who study cities and their problems should draft a list of criteria by which the cluster settlement (geographic or agglomerated city) could be delimited and its boundaries drawn before the 1970 census is taken.

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2. U. S. Bureau of the Census, **U. S. Census of Population: 1960, Vol. 1, Characteristics of the Population.** U. S. Government Printing Office, Washington, D.C., 1963.
3. Agglomerated is a term used in the **United Nations' Demographic Yearbook,** 1962, to designate the population of the political city and adjacent areas.

Some Aspects of the Drainage Geography and Sedimentation of a Portion of Southeastern Texas

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Introduction and Location

The major drainage features of the extreme southeastern portion of Texas are the Neches and Sabine Rivers, Sabine Lake, and Sabine Pass. The nearby parts of the Gulf of Mexico are included in the overall drainage concept of the area. The north boundary of the entire drainage area is approximately 33° north latitude; the south, approximately 30° north latitude; the east varies between 93° and 94° west longitude; and the west between 95° and 96° west longitude. The area measures roughly 320 miles in length and approximately 115 miles at its maximum width and includes an area slightly in excess of 20,000 square miles (Fig. 1).

Drainage Basins

The Neches and Sabine Rivers drain a combined area of approximately 19,830 square miles into Sabine Lake. These basins are underlain predominately by Tertiary and Quaternary deposits, along with a minor amount of Cretaceous sediments. The deposits are mainly sand, silt, clay, and marl, and some gravel in the Quaternary section.

The Neches River rises in eastern Van Zandt County and flows south approximately 260 miles to enter the north end of Sabine Lake. The Angelina River, formed by the junction of Barnhardt, Scobee, and Shawnee Creeks in southwestern and central Rusk County, flows southeast to empty into the Neches River in northwest Jasper County, some 12 miles west of the town of Jasper. The drainage basin of the combined streams comprises approximately 10,130 square miles.

The Sabine River heads in three main branches—Cowleach Fork, Caddo Fork, and South Fork—all located in Hunt County. About 40 miles downstream from the junction of these three branches, a fourth branch, Lake Fork Creek, joins to form the Sabine proper. The Sabine River flows approximately 360 miles and empties into the northern part of Sabine Lake. The Sabine River drainage basin covers approximately 9,700 square miles.

The combined discharge of the two rivers, plus a small amount of discharge from minor streams emptying into Sabine Lake, particularly from the east side, passes into Sabine Lake, through Sabine Pass, into the Gulf of Mexico. Part of the discharge from the rivers is diverted into the Port Arthur and Sabine-Neches Canals. It is estimated that 25 to 30 percent of the major flood volume is diverted through the canals (1).

Run-off and Sedimentation

From records obtained from the U. S. Corps of Engineers (no date), measurements are presented on the amount of run-off and sediment discharged by the Neches and Sabine Rivers into Sabine Lake.

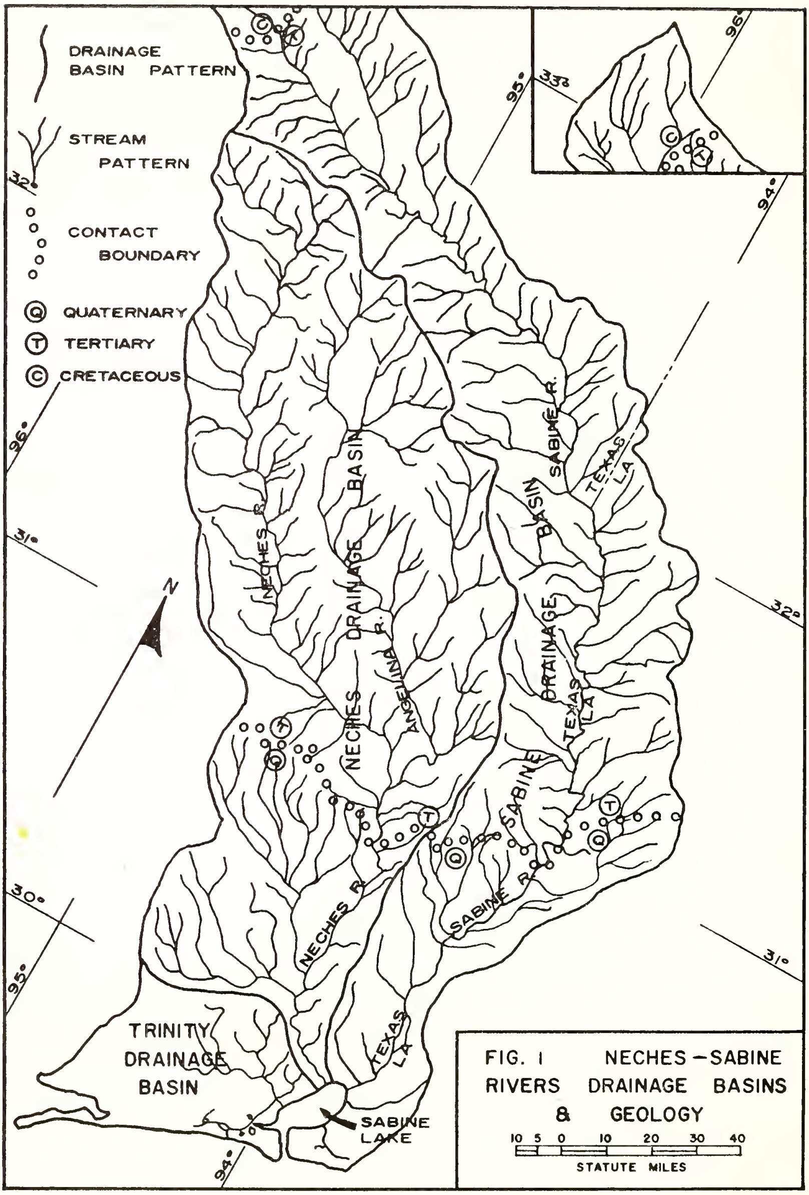

Figure 1

The two nearest stream-gauging stations from which discharge records are available are those located at Evadale (River mile 55) on the Neches River and Ruliff (River mile 40) on the Sabine River. The stream at the Evadale station has an average annual run-off of 4,800,000 acre-feet with the annual run-off varying from 1.72 inches minimum to 21.83 inches maximum, or an average annual run-off of 11.36 inches. The stream at the Ruliff station has an annual run-off of 6,600,000 acre-feet with the annual run-off varying from 2.44 inches minimum to 24.75 inches maximum, or an average annual run-off of 13.10 inches. If the average rate of run-off below the gauging stations is at the same rate as above them, then the total discharge of the Neches River averages 6,050,000 acre-feet annually and the total discharge of the Sabine River averages 6,850,000 acre-feet annually. The combined discharge of the two streams into Sabine Lake averages 12,900,000 acre-feet annually, part of which is diverted into the nearby canals.

Data on the amount of natural sediments carried by the two rivers were obtained from samples taken by the Texas Board of Water Engineers in cooperation with the U. S. Department of Agriculture. The sampling stations were located as follows:

River	Station	Location
Neches River	Rockland, Texas	158 miles above Sabine Lake on a Neches River tributary
Angelina River	Horger, Texas	138 miles above Sabine Lake
Sabine River	Logansport, La.	267 miles above Sabine Lake

Samples taken were of the suspended load only; no samples were taken of the bed load, although it probably represents a considerable part of the total sediment carried by the streams. The actual sedimentary load must be greater than indicated by the sediment-sampling measurements.

On the assumption that a cubic foot of silt weighs 70 pounds, it was calculated that the average annual suspended sediment load of the Neches River at Rockland is 294 acre-feet or 474,000 cubic yards; of the Angelina River at Horger, 360 acre-feet or 581,000 cubic yards; and of the Sabine River at Logansport, 694 acre-feet or 1,120,000 cubic yards.

Because the sediment-measuring stations are located some distance above Sabine Lake, the calculations do not truly represent the total sediments carried into the lake. However, taking the estimated average annual discharge at the mouth of the river and the percentage of silt load obtained at the several measurement stations, the total suspended sedimentary load is 900 acre-feet or 1,455,000 cubic yards from the Neches River and 1,630 acre-feet or 2,630,000 cubic yards from the Sabine River. This makes a combined average annual sediment discharge into Sabine Lake of 2,530 acre-feet or 4,085,000 cubic yards. The average suspended load in the two rivers is approximately 220 parts per million.

Prior to the construction of the Sabine-Neches Canal, the total load of sediment was deposited in Sabine Lake. Since the construction of the canal, it is estimated that 25 percent of the total suspended load is diverted into the canal and approximately 1,900 acre-feet or 3,000,000 cubic yards of sediments are discharged directly into the lake. If the average annual load were deposited uniformly in Sabine Lake, it would cover the bottom with a mantle of materials about 0.03 feet thick. Of the naturally deposited materials in the lake, a small part ultimately is carried through Sabine Pass and into the Gulf of Mexico. (U. S. Corps of Engineers, no date.)

Shoreline Description

Part of the Sabine Lake shoreline has been modified by man's activities. A spoil embankment between Sabine Lake and the Port Arthur and Sabine-Neches Canals runs continuously along the west shore from Sabine Pass to the mouth of the Neches River. This feature, the result of the initial dredging of the canal between 1892 and 1908 and continuous dredging since that time, is 18 miles long and varies in width from 800 to 3,500 feet. The total area of the embankment is approximately 3,900 acres above mean low tide.

Topographically, the embankment consists of mounds rising 25 to 30 feet above mean low tide; on the lakeside, fringed with marsh grass, is a flat foreshore which, with the probable exception of the bulkhead area opposite Port Arthur, is subject to tidal flooding. Parts of the spoilbank, where small earth levees have been built to retain dredge spoils and are exposed to wave action, are being eroded; the wide marshy flats covered with salt grass and other vegetation are not being eroded as rapidly. (U. S. Corps of Engineers, no date.)

The old natural shoreline, marked approximately by the west bank of the canal, apparently was fairly straight and regular and not too easily eroded. This shoreline was formed by the tough Pleistocene Prairie (Beaumont) clay of the Neches ridge, which was built by a former distributary course of a Pleistocene Trinity River deltaic system.

The eastern shoreline is a natural one, displaying some irregularities and indentations which probably coincide, in part, with the underlying, dissected Pleistocene surface. The lake may be expanding in size in this direction as wave activity erodes the exposed marsh clays.

The northern shoreline is also being modified to a considerable extent by man's activities. Many of the islands located on the northern fringe are spoil-islands resulting from dredging in the nearby canal.

Minor modifications due to spoil-dumping occur along the somewhat sinuous west bank of Sabine Pass. Along the east bank, some of the islands and embayments are the result of dredging activity, causing changes in the shape of the original shoreline.

The Gulf of Mexico shoreline is lobate in the vicinity of Sabine Pass and becomes straight to the east and west of this area.

General Bottom Topography

The basin of Sabine Lake is an elongated depression trending northeast-southwest (Fig. 1). The axis of this depression lies closest to the steep eastern side of the lake. The western side of the depression slopes gently. The southern end has its outlet into the deeper sinuous channel of Sabine Pass.

The isobaths in the northern part of the lake suggest small subaqueous deltas at the mouths of the rivers, particularly the Neches River. The bottom of the Gulf of Mexico in the vicinity of Sabine Pass is a lobate sedimentary platform over which the water is shallow. This is referred to as a subaqueous tidal pass delta. The western part of the delta, divided by the jetties of Sabine Pass, is larger and of flatter gradient than the eastern half. The frontal slope of the western part steepens abruptly at the 12-foot isobath. The eastern half of the delta is less well developed; its slope gradually increases away from the shoreline. The bottom of the Gulf of Mexico, to the east and west of the tidal pass delta, gradually slopes seaward in a regular manner.

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Ohio Landscape Puzzle

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South of Reily, Ohio, a curious hill occupies the southern portion of the broad valley of Indiana Creek. The hill is a little to the east of Route 732 (39°25′38″N, 84°45′36″W) see Reily, Ohio—Indiana quadrangle, and is within the Russell catena of soils over highly fossiliferous limestone of Ordovician age. (4)

It is the thought of this writer that a grit-ladened stream flowed on the top and side of a glacier which filled the valley. The glacier appears to have removed the upland material between the hill and the south side of the valley, leaving the isolated hill. In addition to this the galcier molded the low gradient streams flowing down from the northern upland and shaped the blunt high gradient streams which flow in from the southern upland. The glacial stream left the deep layers of sand on the top of the hill (probably supplemented to a limited extent with wind-blown sand) and shifted flagstone near the hill into a re-aligned horizontal position. (1, 2, 3)

Within the realm of the early Wisconsin glaciation, the upland soils are of Russell catena. Bedrock is of Ordovician age and is a highly fossiliferous, easily fractured sort that breaks readily into cobbles about two inches thick and a foot square. Bedrock outcrops on the hill, and near it, are of this sort.

The hill is located on the south side of the broad valley of Indian Creek, but with bottom land separating the hill from the adjacent upland to the south. High bottom conditions are the rule in the adjacent valley with dissected terraces close to the upland. Streams entering the wide valley of Indian Creek from the north have a low gradient and are blunt in pattern with well defined down-cutting action. A quick glance at the hill south of Reily might lead one to believe that it is a simple erosional feature.

Viewed as a soils problem a different picture emerges. An intergrade of Fairmount and Wynn silt loam is the soil type found on the lower flanks of the hill. Fragments of limestone are common, but cover no more than ten percent of the soil surface. Patches of moneywort, a bog plant, are frequent on the steep slopes (about thirty percent) and appear to be supplied with water by seepage from the hillsides. Farther up on the hillside a Russell, Miami, Hennepin complex exists on slopes of about fifteen percent, with areas of Wynn interspersed. Very few limestone slabs are present and the wetland plants give way to grasses and low shrubs. The hill is capped by deep, very fine sand in which angular glacial pebbles are found. It is difficult, and in most cases unwise, to assign a soils name to such a small area. Coarse grasses grow on the hill's top and a single apple tree occupies the highest position on the hill.

The hill rises from a plateau of 750 feet to 790 feet. Its entire surface is convex with no erosional channels of as much as a foot. Little local erosion appears to have taken place.

The nearby upland to the south, beyond the one hundred feet or more of Genessee bottom soil which separates the hill from the upland, is a north-facing slope of Miami-Russell-Hennepin complex. The bog plant moneywort is much less common here than on the side of the isolated hill and fragments of limestone are not common. Deeply eroded gullies contain large limestone slabs which were probably dumped in by a farmer at the time that the land was in cultivation. A deeper gully to the immediate southeast of the hill shows bedrock limestone. Loose fragments in till seem to have been shifted slightly.

As additional evidence as to the nature of the hill south of Reily, Ohio, an examination of other high hills in the area is important. A little to the south of the church in Reily, and on the other side of Indian Creek, is a hill which is higher than the one first mentioned. (Location 39°25′50″N, 84°45′40″W; see Reily, Ohio-Indiana topo map). The second hill does not have the Fairmont Wynn complex on its lower flanks, but is of the Russell-Miami-Hennepin complex from bottom almost to the top. The top resembles the first hill in having deep, very fine sand with glacial fragments scattered throughout.

It is an interesting exercise to locate three other hills which are to the northwest of the second hill and to draw a line on the topo map connecting them with hill one or hill two. Why do all hills line up so neatly in a northwest-southeast direction? Are they related to the blunted valley appearance of the south side of Indian Creek?

Back to the hill where our discussion started and back to the approach of geology from a soils standpoint. It is the thought of this writer that the hill covers a cone-like bedrock core and that the surface limestone fragments mixed with till have been *shifted*, or moved a very short distance from their place of origin. It is his further thought that the area no longer present between the upland to the south and the hill was removed not by simple erosion, but by the glacier at much the same time that the south face of the valley was molded. That it was molded is indicated by the blunted walls of the valley and short streams which contrast so strongly with the softly sloping stream pattern of the upland on the north side of the valley. Molded as well were the sides of the hill and shifted by glacial or water action were the flagstone fragments that occupy the lower walls of the hill. The seepage areas on the hill side give further credence to the thought of a relatively undisturbed cone of bedrock and weathered bedrock in the central portion of the hill.

None of these conditions are present at hill two, the central portion of which seems to be composed entirely of till, as is the bottom of an adjacent ravine. Hill two can then be thought of as dumped glacial till previously sorted by the glacier and molded to a limited extent by the glacier. Like hill one, it seems to have been subject to considerable water action by a flooded Indian Creek at time of glacial melting. It has suffered normal erosion in the interval between that time and the present. The cap of sand on top of both hills might be explained by wind lifting and movement of small particles at some time following the greatest flood of melt water. This explanation does not account for the numerous pointed small glacial pebbles present on both hills. Were these moved up from the till by action of rodents? If so, a great deal of rodent action must have taken place. Perhaps it has; at this time there are numerous groundhog holes on hill two. High hills have been preferred by groundhogs for a long time.

Another logical explanation and the one most acceptable to this writer concerns a grit-laden stream flowing on the top and side of a glacier which filled the valley. The glacier may be thought of as being the same one that molded the hill and removed the bedrock and till which had previously joined the hill to the upland to the south. The present hill tops of hills one and two may have been the stream bed of that grit-laden stream. This glacier, or an advance associated with it, may have been the one which shaped the low sloping streams coming out of the north side of the valley and molded and blunted the south side of the valley, and shifted the flagstone re-aligning them in a more or less horizontal position.

Soil Descriptions

Fairmount-Wynn complex—rocky soils derived mainly from weathered limestone bedrock with varying amounts of the wind-blown silt known as löess on or near surface. Frequently found on steep slopes.

Russell-Miami-Hennepin complex—deep, well drained, brown soils with varying amounts of löess on or near surface. Gravel, limestone, or till is most often present at depths of ten to thirty feet. Frequently found on sloping land, and occasionally on very steep slopes.

Genessee—a well drained bottom soil associated with rivers flowing through areas of Wisconsin glaciation, or downstream of areas which have been subject to Wisconsin glaciation.

Very fine sand—No effort was made in this text to give a soils name to the very fine sand with numerous sharp glacial fragments found on the two hills. These areas have characteristics of several soils and may be considered as a complex.

Summary

Attention is directed to an oddly shaped hill in southwestern Ohio. The writer rejects the theory of the hill being formed as a simple erosional feature and presents the following viewpoint.

The hill has as its internal core a bedrock cone or block of Odrovician limestone, of the same age and origin as limestone outcrops on the upland to the south. The hill is separated from the upland by bottom land, but by bottom land which has not served as a bed of the river of the adjacent valley (Indian Creek). The surface of the hill consists of till and local limestone fragments which have been moved (or shifted) by glacial action and water movement. Limestone fragments are far more numerous on the lower portions of the hill and this portion of the hill is moist with seepage sufficient to sustain the bog plant moneywort even in time of drought. The higher central portion of the hill's surface is till plastered to the sides of the hill. The surface of the top of the hill is deep very fine sand with numerous sharp glacial fragment.

The hill with its central limestone core was separated from the nearby upland by glacial removal of the bedrock and till. The hill was shaped and molded by the glacier and surface limestone slabs shifted and re-aligned by glacial action and melt water flooding. At one time a river ran on top of the glacier which occupied the valley of Indian Creek. At this time the fine sand with accompanying glacial fragments was deposited in the river bed. The top of the hill represents a portion of that old river bed.

Erosion is considered to be a factor in the hill's present shape, but is not thought to be the only factor, or a principal one.

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Fossil Algae in the St. Louis Limestone of Western Indiana

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General. Various nodular structures invariably turn up in the fossil collections of the Mississippian limestones in Western Indiana. Some of these nodular and brecciated masses are the result of storms or slumps, probably shortly after the time of deposition (1). Other nodules have a more uniform biscuit-like shape, and show a microstructure of ramifying and parallel tubes peculiar to some fossil algae. This latter structure inspired the writer to search for algal limestone in Putnam County and vicinity. The St. Louis limestone with its many differing conditions of ancient sedimentation has provided collecting sites of nodular algal masses, and a number of other specimens which are probably algae. This paper deals mainly with the biscuit-like structures.

In the rocks examined, undoubtedly there are many fossil algal remains that are not recognized. Secondary mineralization has pro-

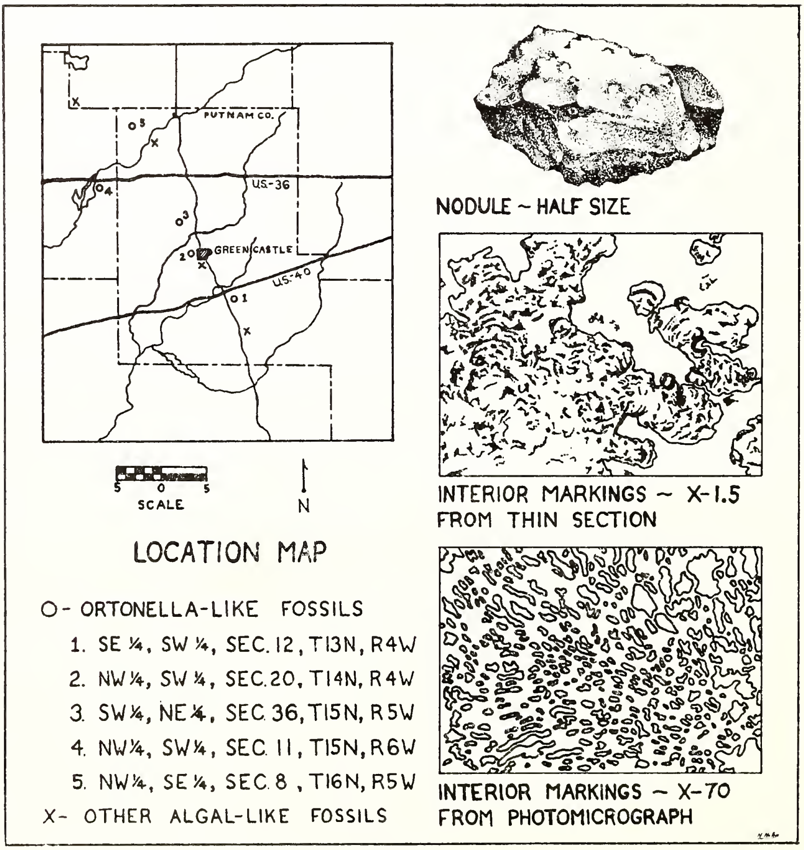
PUTNAM CO.
U.S.-36
GREENCASTLE
U.S.-40
5 0 5
SCALE
N
LOCATION MAP
O- ORTONELLA-LIKE FOSSILS
1. SE ¼, SW ¼, SEC. 12, T13N, R4W
2. NW ¼, SW ¼, SEC. 20, T14N, R4W
3. SW ¼, NE ¼, SEC. 36, T15N, R5W
4. NW ¼, SW ¼, SEC. 11, T15N, R6W
5. NW ¼, SE ¼, SEC. 8, T16N, R5W
X- OTHER ALGAL-LIKE FOSSILS
NODULE ~ HALF SIZE
INTERIOR MARKINGS ~ X-1.5
FROM THIN SECTION
INTERIOR MARKINGS ~ X-70
FROM PHOTOMICROGRAPH

Figure 1

foundly affected the delicate structures of these fossil plants which built calcareous skeletons during Mississippian time. As with calcareous algae of the present, calcification started at the periphery and worked inward. Thus only the more mature plants could be preserved. Too, the intricate mixture of plant and animal preservations at the micro level has resulted in a petrified felt-like structure which at present defies individual identifications.

Descriptions. A representative collecting site is along the north branch of Jones Creek at Vermillion Falls (see Fig. 1), 4½ miles northwest of Greencastle. Here earlier collections have been made from the 30 feet of Mississippian limestone exposed (2). Near the base of the falls along undercut ledges fossil algae are abundant in two beds. The upper bed is two feet thick and is composed of large somewhat flattened algal balls which average 3 to 6 inches in diameter. They weather out and are carried downstream as large cobbles. Directly beneath this bed is a greenish shaly layer 6 inches thick. Smaller flattened and elongate nodules averaging one and one-half inches in diameter are scattered in the limy shale.

The exteriors of the larger nodules are uneven and crinkled, resulting from the growth pattern of the colony. The interiors are solid, but fresh breaks show splochy surfaces. Several specimens of varying sizes were sawed for interior inspection. Thin sections were likewise made and examined. The algal nodule consists of many small rounded nodes which average from one-eighth to one-fourth of an inch in diameter. The structure of each node exhibits a series of fine tubes which radiate from the center. The tubes are packed closely together, and in cross section are nearly round. When the plane of the cut is tangent to the structure the microscope reveals many parallel tubes. Branching of the tubes is limited, but when it does occur banded structure is apparent. Horizontal cuts of the flattened algal nodules produced the best sections for study.

Identification. Fossil specimens are difficult to place in the classification scheme of living material. Nevertheless the attempt is usually made. In the nodular limestones the fossil tube-like structures could be replicas of either animal or plant life. Faunal possibilities might be worm tubes, sponge, coral, echinoderm stems, or others. However, since there are so many closely packed tubes of microscopic diameters, a small bushy-type plant with hardened stems and branches is indicated. The structures are apparently those of calcareous algae.

Earlier workers have assigned such structures to the Blue-green algae, but more recently they are placed under the Green algae in the family Codiaceae (3). The collected specimens compare closely with the genus *Ortonella* (cf. *O. furcata* Garwood). The reported range for this genus is from Silurian to Upper Carboniferous age. A few of the thin section specimens compare with the genus *Garwoodia*, and others with *Solenopora*. It is probable that *Ortonella*, *Garwoodia*, and *Solenopora* are mixed in some of the samples.

Fossil relations. The algal nodules have been found mainly in the lower and middle St. Louis limestone of the Putnam County area. The formation consists of fine to medium grained gray to dark gray limestone, interspersed in the lower and middle beds with some shaly partings. Nodule-like masses are more commonly on the top surface of a limestone bed which may be overlain with thin shaly limestone or shale. The nodules in the limy shale are small, but in more solid limestone may reach 6 inches in diameter. A few other micro-fossil fragments resembling foraminifers are in some of the algal balls. On the whole the rock in which the fossil algae are found is not fossiliferous, save for the algae.

Other questionable fucoidal and stromatolitic structures in the St. Louis limestone of the area are:

(1) chain-like tracks somewhat like small crinoid stems, but probably algae, like *Bevocastria.*

(2) scattered tubes about one millimeter in diameter, filled with calcite, resembling corallites from *Syringopora,* but probably algae, like *Palaeoporella.*

(3) thin, thread-like structures, like *Girvonella.*

(4) laminated, undulating, wavy beds much like stromatolitic limestone, which may include fossil algae, like '*Stromatolites.*'

Paleoecology. An arm of the ocean (entering from the present 'gulf' country) covered this area during lower Meramecian time. The closest shoreline at the time the St. Louis lime muds were being deposited was probably to the eastward some 50 miles (4). Structures in these sediments such as ripple marks and cross beds indicate current action, while faunal assemblages in the rock prove salt water environment. Thickness and extent of limestone in itself indicates shallow portions of warm seas (5).

The presence of fossil algae, and more particularly *Ortonella,* suggest that these conditions prevailed during lower and middle St. Louis time in this area:

(1) lime muds were accumulating on shallow flats.
(2) tides, in protected basins, were very low.
(3) temperature of the water was moderate to warm.
(4) water depth where the nodules formed was from 0-50 feet deep.
(5) variable currents swept the bottoms in gentle motion.
(6) during daylight hours the sun shone most of the time.
(7) the mineral composition of the mud was probably mainly aragonite.
(8) the flattened biscuit-like algal heads represent plant colonies that lived on a rather firm substrate in water that was relatively clear at the time.
(9) algae living in silty water did not thrive. The fossils associated with limy shale are small, and not plentiful. Extreme siltiness spelled an end for *Ortonella.*

Preservation. During St. Louis times many genera and species of algae must have been present in the shallow seas covering the area. At least some of these were lime secreting types, for fossil skeletons are preserved. Originally the lime mud was composed of a complex mineralogical mixture in which an important mineral was aragonite. Through time this mineral has changed to calcite, a more stable form of lime carbonate. The lime from the water apparently is taken first to the outer part of the young plant, and with plant growth, gradually is taken farther into the interior of the skeleton (6). Thus with *Ortonella*, the best preserved structure is on the exterior of the small plant units, while the inside is a sponge-like mass of limestone. Even so it is hard to believe that such delicate plant structures could be preserved, especially since secondary changes have gone on after petrefaction.

Usefulness. Fossil algae take so many structural forms that even identification as a plant may be difficult. Indeed many collectors of the past have probably placed some fossil algae in various other divisions such as sponges, corals, bryozoa, crinoids, worms, and others. Some algae, like *Ortonella* are rather distinctive. For this area at least, and as now interpreted, recognition of this fossil is an aid to sequence studies in the lower and middle St. Louis limestone. Other genera of fossil algae are present in the Mississippian rocks of the area and should be collected and studied for further stratigraphic use.

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Groundwater Movement and Cavern Development in the Chester Series in Indiana[1]

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The hills and valleys of the Crawford Upland of south-central Indiana (Figure 1-A) are underlain by rocks of the West Baden and Stephensport Groups (Chester Series) (Figure 1-B). These rocks typically consist of repeated sequences of dense jointed limestone underlain by shale and overlain by thick jointed sandstone. Groundwater movement is mostly within the sandstones and limestones, for the shales are relatively impermeable. Furthermore, groundwater movement seems to be most active in a zone adjacent to the outcrop.

Evidence of ground water movement within the rocks of the West Baden and Stephensport Groups is mostly in the form of springs along the outcrop and solution features in the limestones. The most common solution features noticeable along the outcrop of the limestones are enlarged vertical joints. These are particularly prominent in shallow road cuts and quarry exposures. The solution of limestone along bedding planes is uncommon except at the base of the limestones, and is secondary to solution along vertical joints. Small solution channels are common along the base of the limestones and some of these feed small springs that are characteristic of the Crawford Upland. Larger solution channels and caverns feed larger springs, usually situated in spring alcoves, although many of the caverns cannot be entered because their entrances are blocked by collapse of the rock faces above the springs.

Caves are abundant along the outcrop of the various West Baden and Stephensport limestones (3). Most of the caves are small and extend only a short distance from the outcrop to places where the passage is blocked by collapse material or becomes too small to traverse. McGrain and Bandy (1) described four short caverns in the Beech Creek Limestone which are typical of most caverns in limestones of the Chester Series. They stated that ground water from the overlying sandstone supplies the water for cavern development by joint enlargement, and that modification by collapse is minor.

The areal extent of the outcrop of the relatively thin limestones of the West Baden and Stephensport Groups is very limited in comparison to the underlying thicker limestone of the Blue River Group which crop out extensively on the Mitchell Plain to the east of the Crawford Upland. Karst features, which are typical of the Mitchell Plain, exist but are not common on the limestone surfaces of the Crawford Upland. The lack of sinkholes and sinking streams on some limestone surfaces of the Crawford Upland that are known to be underlain by well developed caverns indicates that these caves have been formed by some means

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[1] Published with permission of the State Geologist, Indiana Department of Natural Resources.

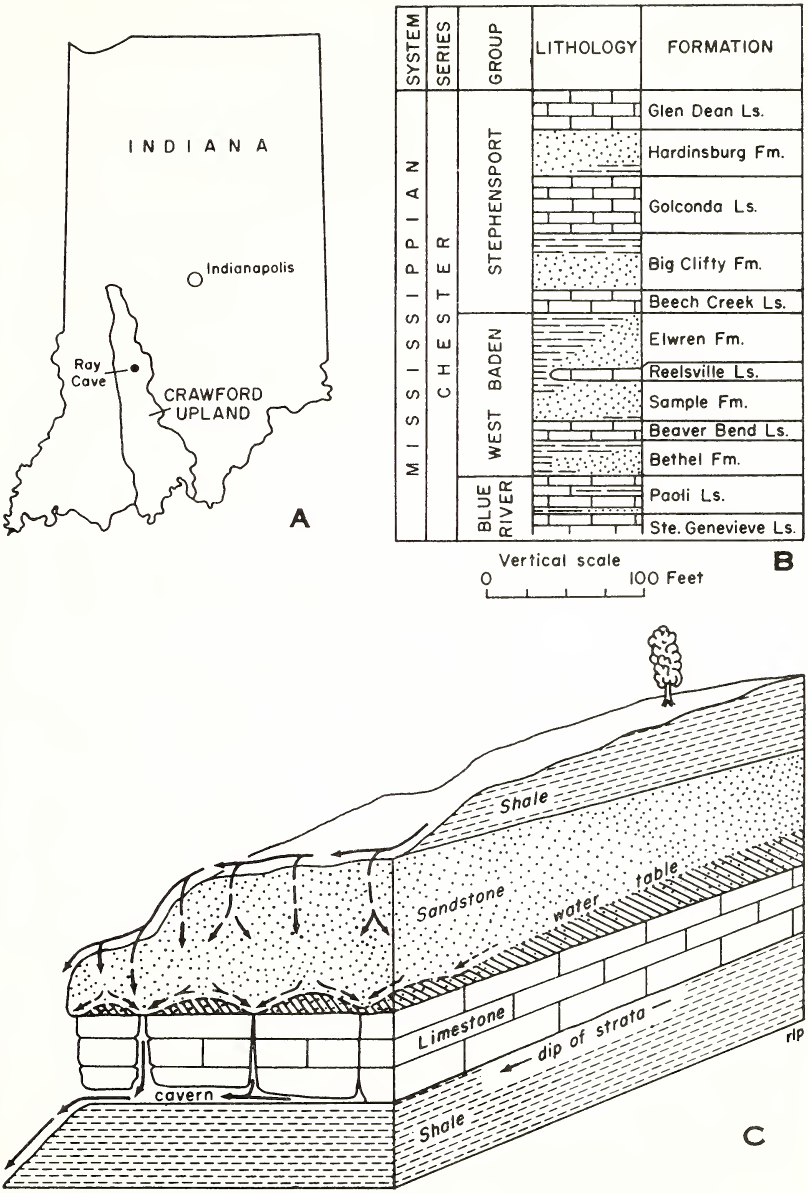

Figure 1

A. Map of Indiana showing the location of the Crawford Upland and Ray Cave.

B. Generalized stratigraphic column showing the rock types of the West Baden and Stephensport Groups.

C. Idealized block diagram showing the relationships of groundwater movement to rock types.

other than by the type of subterranean stream piracy or stream diversion that is characteristic of the Mitchell Plain.

Sinkholes have developed on locally extensive limestone surfaces in the Crawford Upland, particularly on the thicker limestones. Most of these are collapse sinkholes, which have developed over caverns where the limestone has been removed from a larger area than the overlying rocks can span without collapsing.

Caverns within the Chester limestones are nearly always situated where the limestone is underlain by shale and overlain by permeable sandstone. The outcrop of the limestone in the vicinity of many of the caverns consists of a nearly vertical face beneath overhanging ledges of sandstone. Thus the limestone has practically no areal extent on the outcrop except where an occasional gully has been eroded through some of the sandstone.

Groundwater within the sandstones and limestones of the West Baden and Stephensport Groups is derived from direct infiltration of precipitation plus some surface run-off from the hillside (Figure 1-C). Run-off descending the slope above the sandstone cannot enter the sandstone to become groundwater until it has passed over the lowest overlying impermeable zone, generally a shale. Thus the zone of surface water infiltration is closely related to the areal extent of the outcrop of the sandstone. The water is not uniformly absorbed by the sandstone because of local differences in permeability. Water entering a permeable sandstone descends rapidly to the water table where it moves laterally to a release point. Inasmuch as the standstones are commonly underlain by rocks of even less uniform permeability, groundwater in the basal part of the sandstone constitutes a perched water body. If shale underlies the sandstone the groundwater must flow laterally to a spring at the outcrop or to where a more permeable lithology underlies the sandstone. Where jointed limestone underlies the sandstone, descending groundwater flows laterally on top of the limestone, then downward into joints in the limestone. The volume, rate and direction of flow of water from the sandstone depend upon the amount of water available and the size and spacing of the openings along the joints at the upper surface of the limestone.

The movement of water through the limestone depends upon the character of the jointing. Two sets of joints are common, but systems with three, four and five sets are known. The amount of open space along these joints determines the rate and volume of water that may enter the limestone. Many of the joints that can be viewed from within a cave are tight and do not appear to be water bearing; others range from shallow to deep and narrow to broad crevices. Joints are generally more widely opened along the outcrop where mass wasting has caused slight movement of the blocks of limestone.

Groundwater descending through joints in the limestone differentially dissolves portions of the walls of the joints. The magnitude of solution depends upon the acidity of the water, its amount and rate of flow, and the solubility of the limestone with which it comes in contact. In general, the greater the rate of flow, the greater the rate of solution;

therefore those joints which receive the greatest amount of water are those most likely to be further enlarged. Nearly all cave passages in the limestones exhibit joint control (1).

Shale most commonly underlies the limestones of the West Baden and Stephensport Groups. Water descending through joints in the limestone is therefore forced to flow laterally along joints near the base of the limestone, thus forming a second perched water body. Secondarily enlarged bedding plane surfaces and horizontal solution scars are occasionally prominent in the otherwise joint controlled passages. Water is released from the narrow vertical joints either into cavern passages or to the outcrop. The caverns usually open onto the outcrop within a spring alcove formed by erosion of the impermeable shale downstream from the entrance of the cave, subsequently undermining the jointed limestone, and causing mass wasting of the limestone and overlying sandstone.

Ray Cave, located at the type locality of the Beech Creek Limestone, shows the close relationship of a typical cavern to the outcrop. The limestone here is 24.5 feet thick and is overlain by 37 feet of sandstone and 20 feet of shale and underlain by 46 feet of shale and sandstone (2). Ray Cave is developed down the dip of the strata, which is to the west at about 45 feet per mile in the vicinity of the cave (Figure 2-A).

Ray Cave is the longest known cave within limestones of the West Baden and Stephensport Groups. It consists of passages that have been mapped for a distance of about 9000 feet without finding a terminus. The cave contains a small stream for its entire length. The main passage is large enough to permit walking, but many collapsed areas require climbing and crawling over and through breakdown. There are few side passages, but there are two in the downstream part of the cave (Figure 2-B). One side passage near the entrance extends from the cave stream level in the main passage to the top of the outcrop of the limestone, and another trends northward along the ridge. A third opening to the surface extends through the sandstone at the first collapsed area across the main passage.

Ray Cave closely follows the surface exposure of the Beech Creek Limestone, rather than meandering at random beneath the ridge (Figure 2-A). The cave lies within 300 feet of the outcrop for most of its mapped distance. The greatest known distance from an adjacent outcrop is about 700 feet, which is at a place where the cave passes beneath a small spur north of the main ridge (north of Combs School). The main ridge has an average width of about 3000 feet at the level of the Beech Creek Limestone and is about 2000 feet wide at its narrowest place, near the eastern or upstream end of the mapped cavern.

Ray Cave contains numerous domes ranging from 15 to 20 feet high which extend upward from the ceiling of the cave passage, often to the base of the overlying sandstone. In addition, there are several high open joints. These vertical solution features indicate that water has entered the cave from the top of the limestone, and most likely from the overlying sandstone. The domes and high fissure passages are located where Ray Cave is closest to the outcrop (Figure 2-B). Some

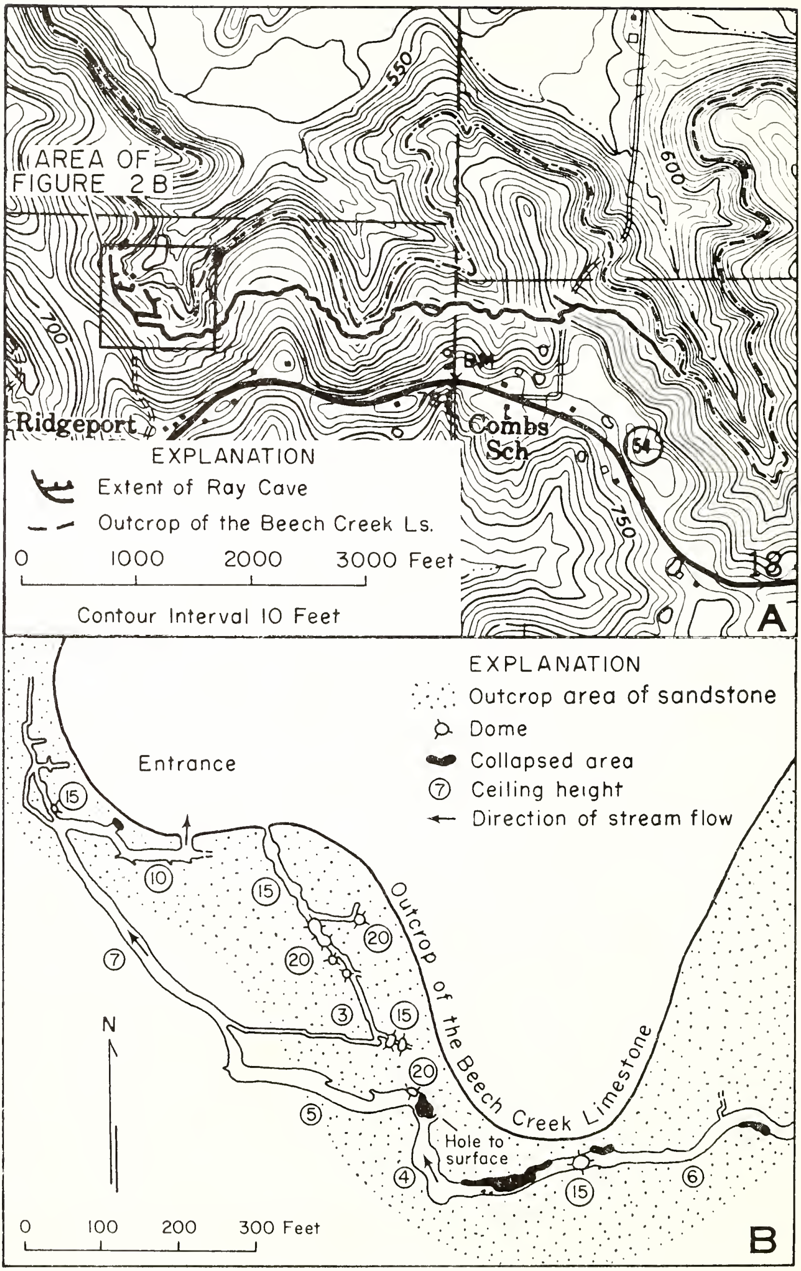

Figure 2

A. Topographic map showing the location and extent of Ray Cave and the outcrop of the Beech Creek Limestone. Base modified from the Solsberry Quadrangle.

B. Map of the downstream portion of Ray Cave showing the relationship of the Cave to the outcrop of limestone and sandstone.

water enters the cave passage at the collapsed areas which are also very close to the outcrop (1). The collapsed material is mostly limestone but contains some sandstone blocks and sandstone is exposed at the top of several of the collapse areas. Collapse and vertical solution features are not found where the cave lies more than a few hundred feet from the outcrop.

No sinkholes are known along the ridge above Ray Cave nor adjacent to the outcrop of the Beech Creek Limestone. Thus, the stream in Ray Cave is not fed by surface drainage as are the caves beneath the Mitchell Plain. The flow regimen of Ray Cave is not similar to that of a stormwater cavern. The stream in Ray Cave does not appear to dry up completely, as do some stormwater caverns, nor does it appear subject to flash flooding. The observed and inferred flood levels in Ray Cave are low in comparison to those of stormwater caverns. Similar observations have been made for most of the caves in limestones of the West Baden and Stephensport Groups. The relatively uniform permeability in the sandstone and the storage capacity of its perched water body may serve to regulate the flow of water in the caves in these limestones.

In summary, the features of the known caverns in all of the limestones of the West Baden and Stephensport Groups indicate the direction and amount of groundwater movement within the caverns and the overlying strata. The presence of high open joints and domes in these caves is proof that groundwater has entered the cave from an overlying permeable zone. The nearness of the caverns to the outcrop indicates that there is a close relationship between amount of groundwater flow and proximity to outcrop. The cavern passages tend to follow widened joints down the dip of the strata. The flow characteristics of the springs and caverns indicate that the flow is somewhat regulated, perhaps by storage and release of water from an overlying perched water body which is recharged by surface run-off and precipitation. Although the caves are not generally associated with surface karst features which would indicate their presence, the collapse of the cave passage at points near the outcrop creates surface openings for the direct infiltration of small amounts of surface water.

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HISTORY OF SCIENCE

Chairman: Nellie Coats, State Library
Lawrence H. Baldinger, University of Notre Dame, was elected chairman for 1966

A Brief History of the Pharmacy College of Butler University

K. L. Kaufman, Dean

This college traces its origin to the religious group known as the Winona Assembly and Summer School Association. It was decided about 1902 that the organization should sponsor agriculture and technical schools. It was further envisioned that the agricultural department of the school should be established at Winona Lake and the technical departments at Indianapolis. During the year 1903 there was further discussion and planning for the trade school portions of the Institute, and on March 16, 1904, the supporters of the movement purchased the grounds of the United States Arsenal on East Michigan Street. This property was made available by the government at relatively low cost with the proviso that it must be used for educational purposes. Incorporation papers were filed on April 7, 1904, under the name of Winona Technical Institute (see Fig. 1). The property included more than seventy-six acres, partly forested and part under cultivation. There were numerous brick buildings easily convertible to teaching uses.

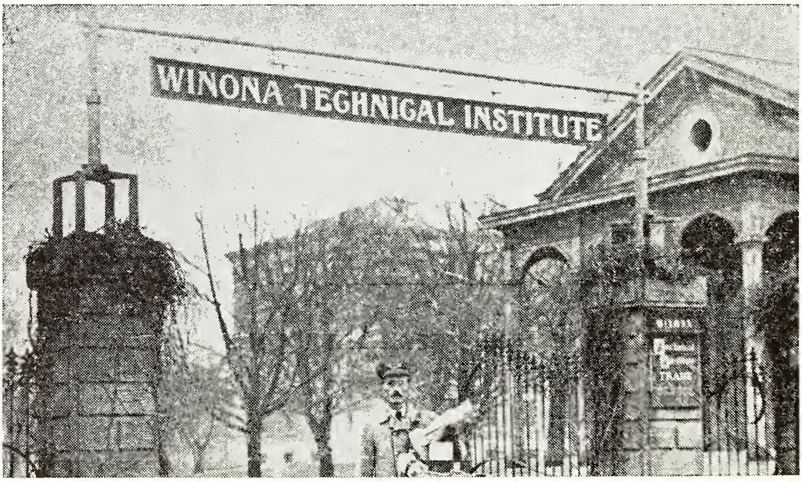

Figure 1

Money for this operation was raised almost entirely in Indianapolis from then well-known individuals. A total of $350,000 was secured, although no provision was made for endowment of the Institute. All of the major donors became trustees, so that the original group not only had a large number, but the list read like a roster of "Who's Who." Among these well-known names were A. C. Atkins of the saw company, Allison, whose name survives in one of the major divisions of General Motors, Mr. Burdsall of the paint family, Mr. Hanna of the Atlas Engineering Company, Mr. Holliday and Mr. Jordan of the Trust Companies. Mr. Smith of the Indianapolis News, and the creator of the Indianapolis Foundation was another, and H. J. Heinz of pickle fame also participated, while John Studebaker was another well-known name on the list.

The Institute opened its doors for its first students on September 6, 1904. Departments of pharmacy, chemistry and electrical wiring were among those originally operated. A little later, lithography and house and sign painting, were added to the list. In addition to these, departments of printing, carpentry, molding, tile setting, machinery, applied sciences and brick laying came into operation two or three years later.

A total of 80 students were enrolled the first year, of which twelve were studying pharmacy. The first director of pharmacy was Professor John A. Gertler, who came to the school from Ohio Northern University. In the second year, 50 students were in the pharmacy program. During the school year of 1907 and 1908, the total enrollment reached 500 students. More than two hundred pharmacy students had enrolled by 1909, and 125 had been graduated. In that period, the college "year" was only twenty-six weeks in length, and two such terms sufficed to earn the Ph.G. (Pharmaceutical Graduate) degree. If the student chose to attend an additional ten weeks each year, he could receive the Ph.C. (Pharmaceutical Chemist) degree.

In 1910 the Pharmacy department was moved to the main building because of its growth. Professor Gertler met an accidental death in 1911 and was succeeded by Professor A. F. Haller, one of his classmates from Ohio Northern University. He also died in an accident in 1912 and was succeeded by F. A. Mueller, who continued as Dean until 1921. During the first four years of operation, many improvements were made upon the substantial buildings which had been bought from the Government, and a new building added for use of the foundry school. In 1908-09, the management of the Institute claimed in its catalogue that the property was admirably adapted to the needs of the school.

By 1908 or 1909, the Institute had fallen upon hard times. Some few alumni with which the writer has discussed the early history of the organization, indicate that some of the funds were believed to have been stolen. At any rate, the Pharmacy department was the only part of the Institute which had prospered. By 1913, debts accumulated, litigation ensued, and the Indianapolis School System took over the property.

The Pharmacy department, stimulated by the needs of the community's pharmacists and by the major pharmaceutical manufacturing operations in the area, secured some financial support specifically for its own use and proceeded to move to the 7th floor of the Century Building at Maryland and South Pennsylvania Streets and continue operations. A new charter was obtained in 1914, and Professor Ferdinand A. Mueller became President and Dean. Mr. Mueller was a brother of the original Mueller of the Mooney-Mueller-Ward Company, wholesale druggists. The Treasurer of the College and a teacher at this time was

John Fritz, elder brother of Albert C. Fritz, who will be mentioned later. The College changed its name to The Indianapolis College of Pharmacy and remained completely independent of other affiliations for about thirty-seven years. It should be noted that Charles Bookwalter, the city's Mayor, exerted great influence to acquire funds and space to assist the College.

In 1919, a home was purchased for the College at 522 Fletcher Avenue and classes began there in 1920. The property included two brick buildings with about fifteen rooms available for class and laboratory work. By 1922 this facility was outgrown. Finally, in 1924 the old Indiana Veterinary College became bankrupt and offered its property at 802 East Market Street for sale. Dean Niles borrowed approximately $50,000 from the manufacturers and wholesalers of Indianapolis to acquire this property and some additional equipment. Elderly alumni tell me that this money, while technically made available to him as a loan, was actually considered by the supporters as a gift. They were much surprised when Dean Niles repaid this loan.

In the meantime, the Pharmacy curriculum had been changing from the trade-school style to a true academic and professional program. This change, of course, made the cost of operation much higher and the necessity for increased funds became more pressing. A minimum three year course was adopted in 1925, but the Ph.C. degree was retained. In 1930, the College adopted a minimum four year program, two years before it became mandatory, and was thus one of the first ten schools to enforce this standard. The College was inspected and approved by the American Council on Pharmaceutical Education in 1941. World War II caused the College to adopt the accelerated program as did most others, and it was continued from 1942 until 1946.

It may be noted in passing that it was in the period 1930-1945 that most of the independent colleges of pharmacy across the country, either closed or arranged affiliations with other institutions, as a matter of insuring their survival.

In the late 1930's, informal discussions between Dean Niles and representatives of other institutions began. There were those in the pharmaceutical community who thought that a merger with Indiana University would be desirable, and presumably some who mentioned various other private institutions. Butler University came forward with the most agreeable mutual arrangements, and in September, 1945, the articles of consolidation were executed. An understanding was reached that representatives of the pharmaceutical community would set forth on a program immediately to raise sufficient funds to build and equip a modern College of Pharmacy on the Butler campus.

Mr. Albert C. Fritz, a long-time friend of pharmacy, a graduate of the College, and a community pharmacist of Indianapolis was one co-chairman of a group in charge of raising the funds and Mr. William Mooney, Sr., who was then President of the Mooney-Mueller-Ward wholesale drug firm, was the other co-chairman. These gentlemen, assisted by many friends, obtained gifts from more than 600 sources. With these gifts, plus approximately a quarter million dollars supplied from University funds, the College opened its doors at its new location on the campus in September, 1951. Ground breaking ceremonies had been held in October, 1949, and the corner stone laying had taken place on June 20, 1950. The University later sold the old property at 802 East Market Street, which had been the home of the College for more than twenty-five years. When the new building was dedicated on May 7, 1952, the library was designated officially as the Edward H. Niles Library in recognition of his long and devoted service to the College. Dean Niles retired at the close of the first year of work at the new building and was succeeded by Dr. Karl L. Kaufman.

The College, since coming to the campus, has turned over most of the basic sciences and all the general education courses to the appropriate departments in Butler's College of Liberal Arts and Sciences.

A full-time faculty of ten, plus seven part-time teachers take care of the instruction in the professional areas. Nearly all hold the Ph.D. or other doctoral degrees.

Since 1952, the College has conducted a Master of Science program. This program presently embraces major areas of study in Pharmacy, Medicinal Chemistry and Pharmacology. Minors may be selected from these same areas or from the basic sciences or business administration. It is anticipated that work in Pharmacognosy and Pharmacy Administration will be added to the graduate program a little later.

The principal sources of the graduate students have been two: 1) employees of local industry who undertake graduate work on a part-time basis, and 2) baccalaureate degree holders of our own College who chose to stay with their old teachers until they had completed the M.Sc. degree, many then going on to doctoral studies at various universities.

In 1956, the College made available an optional program covering five academic years. This curriculum became compulsory in 1960. In keeping with the traditions of Butler University, the College provides a strong background in liberal arts to all students now enrolled.

Butler University should continue its growth and development under a dynamic new administration. As the Holcomb Research Institute, for which the University has received substantial financial support, becomes operational, the faculty looks forward to continued challenge and growth of the College, particularly in its graduate programs.

A Note on Sources

Material for this paper has been obtained primarily from:

1. Old catalogue of Winona Technical Institute.
2. Yearbooks of the Indianapolis College of Pharmacy ("The Mistura")
3. Article by Dr. Niles in "Indiana Pharmacist," and
4. Interviews with Mrs. Niles and Mr. Albert Fritz.

History of Germfree Animal Research at Lobund Laboratory, Biology Department, University of Notre Dame, 1928-1965

JULIAN R. PLEASANTS, University of Notre Dame

The first published report (7) of germfree animal rearing at Lobund Laboratory was presented to the Indiana Academy of Science in 1932, by James A. Reyniers, who had inaugurated the program of germfree animal research at Notre Dame in 1928, and directed it until 1958. In 1939, a colloquium on micrurgical and germfree methods, the first of its type, was convened at the University of Notre Dame, and the ambitious range of the Lobund program was there revealed. When the proceedings were published in book form in 1943 (8), they included a summary of the Lobund program as it had developed up to 1942.

In 1944, another historical summary of the Lobund research program was included in a history of bacteriology research and teaching (3) presented to the Indiana Academy of Science by Robert F. Ervin, who had been associated with Lobund activities since 1936. The word "Lobund" is derived from the initial letters of the term: Laboratories of Bacteriology, University of Notre Dame. The teaching of bacteriology and strictly bacteriological research have been continuing activities of Lobund. Prominent also in the early years of the Lobund program was research in micrurgy, or micro-manipulation, and most of the early publications (8) dealt with this approach to bacteriology. The name "Lobund," however, has come to be associated primarily with the program of germfree animal research, and it is this program which will be summarized below.

A laboratory which is pursuing an ambitious, long range, and stepwise program provides an inviting topic for historical summation. Ervin provided other summaries in 1946 (1) and 1949 (2). The major publications on the rearing of germfree rats and chickens were presented in somewhat chronological form in Lobund Reports Numbers 1, 2, and 3 (1946, 1949, 1960) published by the University of Notre Dame Press. Summary articles were published by Reyniers in 1957 (9) and 1958 (10). A chronology fitting the Lobund effort into the total picture of germfree animal research was included in a 1963 book by T. D. Luckey (4) who was associated with the Lobund program from 1946 to 1954. Lobund history was further brought up to date in 1964 (6) by Morris Pollard, director of Lobund since 1961. The sources for a history of germfree animal research may be conveniently located in a bibliography of germfree research (11) published in 1963 by B. A. Teah, a member of the Lobund staff since 1943.

In order to simplify the presentation of Lobund history, I have divided it into periods which correspond to the four phases of the Lobund program decided upon by its founder in the years 1928-1930. The events, of course, cannot be so neatly divided. Apparatus development did not stop when germfree colonies were obtained. Also, valuable scientific observations were made on germfree animals even during experiments set up to test apparatus. Nevertheless, there is a certain parallelism between the events and the original plan as published in (8), and this plan provides the basis for the following chronological division:

1928—1944	a.	The design of appropriate apparatus.
1945—1954	b.	The successful rearing of a variety of germfree species.
1954—1958	c.	The testing of the animals for uniformity and general acceptability in experimental research.
1959—1965	d.	The use of germfree animals in various aspects of bio-medical research.

First Period. 1928—1944. Reyniers' original concern was to apply engineering principles to assure the isolation of individual microorganisms from all other microorganisms. In 1928, bacteriology had been carried on for 50 years with techniques little different from those of Koch and his contemporaries. These did not, however, provide absolute security from contamination. In the course of developing equipment which would provide secure isolation of microorganisms, Reyniers soon realized that it would have a much broader range of usefulness, permitting also the isolation of higher organisms from microorganisms. Furthermore, a germfree animal, as a living culture medium, would provide a very critical test of any isolating system.

Germfree animal research was already 33 years old (5) when the Lobund program started. However, up until then germfree animals had been reared primarily to test the prediction of Pasteur (4) that an animal would not be able to live without germs. What Lobund brought to the field of germfree research was a determination to turn the germfree animal from a scientific curiosity into a useful experimental tool. This demanded a continuity of effort which was provided in this period by the research team of J. A. Reyniers, P. C. Trexler, R. F. Ervin, A. W. Phillips, J. F. Reback, M. Wagner and B. A. Teah with the support of Dean of Science Francis J. Wenninger, C.S.C. and President of the University John F. O'Hara, C.S.C.

During this period, air-tight containers had to be developed which could be sterilized on the inside and then used to maintain and manipulate the germfree animals. Air filtration methods were devised and tested. Food sterilization techniques had to be developed which did not destroy the nutritional value of the diet. Procedures for detecting leaks and contaminations were worked out, as well as the means for preventing them. A practical technique for caesarian delivery of young mammals into the germfree system, and a method of surface sterilization of chicken and turkey eggs were developed.

Although development of apparatus in this period was basic to germfree animal research, the broader usefulness of this development may be seen in its application to the control of airborne cross-infection in hospital nurseries and in army barracks, and to the protection of laboratory personnel from highly infectious bacteria. In 1937, Lobund had moved from a few rooms in the old Science Hall to 22 rooms in the ground floor of the new Biology Building. During World War II some of these facilities were diverted from the rearing of germfree animals to the propagation, processing and study of infectious bacteria, with the objective of developing defenses against microbiological warfare. Here the germfree system was successfully used in reverse to keep the germs in—away from laboratory personnel.

This first period had seen the rearing of germfree guinea pigs, monkeys, and chickens through the early portions of their life span. It was now evident that the apparatus was adequate for maintaining animals through long periods, and the way was clear for development of colonies of reproducing germfree laboratory animals, particularly the much-used species: rats and mice.

Second Period. 1945—1954. With the close of World War II freeing some of the staff and facilities, Lobund could now concentrate on the germfree animal itself. It received new support for this effort from the Dean of the Notre Dame Graduate School, Rev. Philip S. Moore, C.S.C., and from the Office of Naval Research. It will already have become evident that the original 4 point Lobund program cuts across all lines in the areas of biology, chemistry, and engineering. The first period's emphasis on microbiology and engineering now gave way to more emphasis on the germfree animal, its physiology, nutrition, anatomy and even its psychology. New staff members active in these fields were added: J. R. Pleasants, H. A. Gordon, T. D. Luckey. In the case of rats and mice, which are very immature at birth, it became necessary for Lobund to pioneer in the development of artificial milk formulas and hand-feeding methods which could be used to rear these germfree mammals from caesarian birth to weaning, since this was the only means by which such species could be obtained germfree.

Concentrated efforts in 1945 resulted in the first successful weaning of germfree rats and the first successful reproduction by hand-reared (but accidentally contaminated) rats. Initial dental and nutritional studies were carried out with hand-reared rats, but the whole operation was put on a much more secure basis in 1950, when full-scale colony production of germfree rats expanded into a new building designed specifically for germfree life research. With the dedication of this building, Lobund was also organized as an institute within the University of Notre Dame.

During this period, germfree chickens were obtained in quantity and subjected to an extensive survey to determine their physiological, nutritional and morphological parameters of normalcy, a survey which indicated their potential value as an experimental tool. They were applied to experiments designed to explain the then recent discovery that antibiotics could increase the growth of farm animals. Repression of certain elements of the intestinal bacterial flora was implicated as the main cause of the increased growth rate. Early work in germfree rat nutrition was also able to prove decisively for the first time that the rat itself could synthesize an important metabolic intermediate (the labile methyl group) and did not have to obtain it from its intestinal bacteria. Germfree guinea pigs were reared during this period by B. P. Phillips. They were used to show that the dysentery-causing amoeba, *Entamoeba histolytica*, was very much dependent, for its survival in the intestine, upon conditions created by intestinal bacteria. By the end of this period, in 1954, the first pair of germfree mice were weaned, and they had produced 300 descendants in the following year. Thus, by the end of the second period, the problem of producing healthy germfree animals in the quantities required for scientific experimentation had been essentially solved, even though a number of problems, such as the enlargement of the cecum in germfree rodents, demanded further study to improve the condition of the experimental animal itself.

Third Period. 1954—1958. This third and briefer period may be considered an explosive one, in which germfree animals underwent a population explosion, and their production and use expanded out of the Lobund Laboratory into other laboratories in the United States and abroad. While effective means for transporting germfree animals were being developed, a new type of isolator was also developed by P. C. Trexler, who had joined the Lobund staff in 1933 and had done much of the developmental work on equipment throughout Lobund's history. His innovation was an inexpensive and versatile plastic isolator which could be sterilized by a spray of germicide. This made it possible for many laboratories to venture into germfree research without a large capital investment. Lobund rats and mice became the progenitors of germfree rat and mouse colonies in various other centers, and also provided the start of a number of disease-free colonies, which were not maintained under germfree conditions but were maintained free of certain pathogens which had long been known to limit the usefulness of the usual laboratory rats and mice.

With germfree rats, mice, chickens, and guinea pigs now regularly available at Lobund, a period of increasing experimental use began, aided by new staff members, B. S. Wostmann, and the Rev. J. P. Doll, C.S.C. The population explosion was thus followed by the beginnings of a publication explosion, some of the high lights of which are summarized below:

Highlights of Lobund Publications 1954—1958

1954 **Dental studies.** Bacteria are essential for tooth decay. Certain species can produce caries when present as monocontaminants.

Liver necrosis. Bacterially produced toxins are not needed for production of this disease.

1955 **Serology.** Germfree animals show few specific antibodies against common bacteria, but show some so-called "natural antibodies."

Amoebiasis. Pathogenic amoebae do not survive in the intestinal tract of the germfree guinea pig unless certain bacterial associates are added.

1956 **Radiobiology.** Germfree rats show better survival after irradiation than conventional rats.

1957 **Immunology.** Germfree animals show reduced lymphoid tissue and serum gamma globulin.

1958 **Shock.** Bacterial toxins are not needed for production of irreversible hemorrhagic shock.

Nutrition. Penicillin does not improve the growth of germfree rats fed a thiamin deficient diet.

Immunology. Penicillin treated conventional chickens show anatomical characteristics approaching those of germfree chickens.

In 1958, James A. Reyniers ended his 30 years of association with the Lobund program as founder and director. The research administrator for the University, Francis X. Bradley, assumed the role of acting administrative director until 1961, when the post of director was taken over by Morris Pollard, till then professor of preventive medicine and public health at the University of Texas Medical Branch.

Fourth Period. 1959—1965. New staff members were added for increased experimental use of the germfree animal: Brother Raphael Wilson, C.S.C., T. J. Starr and R. J. Downey. In addition to the continued use of the germfree animal as a scientific tool, which will be summarized below, two new species, the sheep and the goat, were added to the germfree list, and the first colony production of germfree guinea pigs and rabbits was obtained. Study of the germfree animal itself, with the goal of increasing its experimental value, was further intensified. A virological survey of the germfree rat and mouse colonies proved generally negative. Subsequently, in 1964 all of the germfree mouse strains were found susceptible to a leukemia induced by four sub-lethal doses of radiation. Thymus glands of the affected animals showed virus-like particles, suggesting the possibility that a virus had been passed into the zygote or through the placenta of the original caesarian-derived animals. This phenomenon is under further study, and efforts are under way to obtain new and virus-free stock for those experiments which require freedom from viruses, including latent ones.

Other efforts to improve the quality of the germfree animal, particularly for nutritional and immunological studies, have involved the development of chemically defined, antigen free diets, in which the exact nutritional intake is known, as well as the degree of exposure to foreign antigens.

Recent uses of the germfree animal at Lobund to answer specific scientific questions are summarized below:

Highlights of Lobund Publications 1959—1965

1959 **Immunology.** Different bacterial monocontaminants may elicit markedly different kinds of immune response.

1960 **Serology and Immunology.** Germfree animals show a complex sequence of responses to added bacterial species and to the action of antibiotics on these species.

1961 **Morphology.** Characteristics of the germfree intestinal tract lead to the suggestion that conventional animals show a chronic intestinal inflammation.

Metabolism. Cholesterol levels in the liver are higher in germfree than in conventional rats. Differences in serum cholesterol depend on age.

1962 **Nutrition.** Thiamin produced by intestinal bacteria is not immediately available to the host.

Immunology. Leucocytes of germfree animals are generally as effective in carbon clearance as those of conventional animals.

1963 **Parasitology.** Germfree turkeys do not succumb to experimental "blackhead" disease.

Oncology. In general, germfree rodents respond to chemical carcinogens as do conventionals, with no association of virus-like particles. A limited variety of spontaneous tumors have occurred in germfree rats and mice.

Radiobiology. Endotoxin is radioprotective for germfree mice. Some bacterial associates may be radioprotective.

Morphology. Germfree rats show reduced cardiac output and lower blood flow to some regions of the body.

Nutrition. Germfree rats succumb rapidly to the effect of a vitamin K deficiency. Natural vitamin K is more effective than the synthetic form for preventing hemorrhage.

1964 **Gerontology.** Germfree rats and mice outlive conventionals. The usual sex pattern of mortality is reversed, germfree males outliving females.

Virology and Oncology. Injected oncogenic viruses produce the same effects in germfree as in conventional mice. Radiation induces leukemia in both germfree and conventional mice, but not in rats.

Immunology. Germfree mice thymectomized at birth show no runting disease or early mortality.

Metabolism. Bacterial action is not necessary to potentiate the hypocholesterolemic effect of certain dietary lipids.

1965 **Dental studies.** The possibility of immunizing against tooth decay is demonstrable in gnotobiotic rats.

Nutrition. When certain diets are fed, intestinal bacteria can play an important role in promoting iron absorption by rabbits.

Immunology. Cortisone increases the mortality of germfree mice exposed to hepatitis virus, but not as much as it increases the mortality of conventional mice.

Radiobiology. Bone marrow transplants permit germfree mice to survive large radiation doses. General radiation resistance in germfree mice is associated with slower mucosal turnover in the germfree intestine.

In this fourth period, as in the preceding ones, the Lobund Laboratory has continued to show its concern not only for short-range experimental use of the germfree animal, but also for the long-range improvement of the germfree animal as a precise experimental tool, through survey of its characteristics, improvement of its nutrition and environment, and exact evaluation of its germfree status. It is these latter concerns, as well as its extensive use of the germfree animal, which has enabled Lobund to play a decisive role in the over-all development of germfree animal research.

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PHYSICS

Chairman: H. K. HUGHES, Indiana State College

ROBERT WISE, Purdue University (Fort Wayne Campus), was elected chairman for 1966

ABSTRACTS

The $Si^{28}(n,\alpha)Mg^{25}$ Reaction—A Student Experiment. M. M. BRETSCHER and D. L. KOHLSTEDT, Valparaiso University.—To demonstrate some of the fundamental aspects of nuclear reactions, a solid state silicon detector was bombarded with 13.61 ± .08 Mev neutrons. With a depletion depth of about 260 microns, the pulse height spectrum from the detector revealed nine alpha particle groups associated with the reaction $Si^{28}(n,\alpha)Mg^{25}$. The corresponding energy levels of the Mg^{25} nucleus were measured to be $0.57 \pm .01$, $0.95 \pm .02$, $1.60 \pm .02$, $1.94 \pm .02$, $2.72 \pm .03$, $3.37 \pm .03$, $3.88 \pm .04$, $4.24 \pm .04$ Mev. These results agree within one per cent of the literature values. Two proton groups from the $Si^{28}(n,p)Al^{28}$ reaction and two alpha groups from the $Si^{29}(n,\alpha)Mg^{26}$ reaction were also identified. The experiment appears to be ideally suited for an advanced undergraduate modern physics laboratory.

Some Considerations for a Simplified Orbiting General Relativity Experiment. RONALD D. PALAMARA, Purdue University.—The synthesis of a simplified orbiting experiment to test the validity of general relativity theory is examined. The original concept, suggested by L. I. Schiff, involved measurement of the relativistic precession of a torque free gyroscope which was located inside a satellite that was orbiting in a gravitational field. This paper considers a highly simplified system in which the satellite is itself the precise orbiting gyroscope. The primary problem areas are reduction of the non-relativistic precessions such that the 7 sec arc/yr relativity precession is a principal effect and measurement of the gyroscope precession. The effect of classical atmospheric, electromagnetic, gravitational, and micrometeorite impact drag torques upon the gyroscope precession is evaluated. By optimizing the orbit parameters and the unshielded gyroscope characteristics, the non-relativistic precessions can be minimized. The total precession is measured by rigidly attaching the proper resolving power lens and folded optics to the inside of the gyroscope. The apparent trace of a stellar reference as viewed by this system and recorded on a photographic plate placed behind the lens is exactly equal to the precession of the gyroscope.

An Hypothesis on the Operation of the Siphon. JAMES C. REBER (Work done as student at Indiana Central College; presently a graduate student and research assistant at Duke University).—Physics textbooks explain the operation of the siphon on the basis of air pressure. It is explained that there is an external pressure due to the atmosphere which forces the liquid up the tube. The difference in the pressure on the two columns is the driving force of the siphon. It is stated that a siphon will not work if the column is higher than that which air pressure will support.

Dr. Konstantin Kolitschew of the physics department of Indiana Central College has proposed an hypothesis contradicting this theory. Dr. Kolitschew suggested that the siphon operates because of surface tension; the fluid continues to flow because of the cohesion between the molecules.

Experiments were designed to test this hypothesis. Capillary mercury siphons were operated in a bell jar at reduced pressure. Experiments were conducted in which the siphon continued to operate at as close to a perfect vacuum as possible with the available equipment (vacuum pump and diffusion pump with rated vacuum of 10^{-6} mm Hg.)

In the course of the experiment it was noted:

1. Vibrations tended to cause the siphon to fail, particularly at low pressure.
2. Siphons in which the upper end had a larger cross-sectional area operated at lower pressures than those in which the lower end had a larger cross-sectional area.

Equations for making an optimum siphon were developed from the general equation:

$$A_2h_2\rho g - A_1h_1\rho g = \frac{\text{(surface tension) (cross-sectional area)}}{\text{(distance over which force acts)}}$$

where A_2 is the cross-sectional area of the longer column and h_2 its height; A_1 is cross-sectional area of shorter column and h_1 its height; ρ is density of the fluid; and g the acceleration of gravity.

It was concluded that although atmospheric pressure is a factor in supporting the column, atmospheric pressure is not the *determining* factor in the possibility of the siphon's action.

Further experiments were suggested using water, water with lowered surface tension, oil, larger siphons, and siphons of varying cross-sectional area to verify the general equations developed.

I would like to give special thanks to Dr. Kolitschew for his encouragement and guidance throughout both the theoretical and experimental phases of this work.

PLANT TAXONOMY

Chairman: GAYTON C. MARKS, Valparaiso University

ABSTRACTS

The Genus *Gleditsia* in North America. DONALD GORDON, Indiana University.—The genus *Gleditsia* in North America is comprised of two species and their putative hybrid. *G. triacanthos* L. is a highly variable species with a wide distribution in eastern North America. *G. aquatica* Marsh. is sympatric with *G. triacanthos* but has a more limited distribution and is usually found growing in or near water. The putative hybrid *G. texana* Sarg. has an extremely limited distribution, reportedly occurring only in isolated counties of Indiana, Arkansas, Louisiana and Texas. Information will be presented concerning the distribution, ecology and variability of the three taxa.

Interspecific Hybridization in the Genus *Heliomeris* (Compositae). WILLARD F. YATES, JR., Ball State University.—The four species of the genus *Heliomeris* occurring in the southwestern United States form a compact group showing close genetic relationships between all members. Under cultivation, interspecific hybrids have been obtained between all four species. The hybrids display surprisingly high fertility and where reduction in fertility is observed it can be largely attributed to chromosomal aberrations rather than to genic sterility. In addition to the artificial hybrids, at least one instance of natural hybridization between species is known. In spite of their obvious close affinities the species are distinct morphologically and should definitely be retained as species. Since genetic barriers to interspecific hybridization appear to be poorly developed, it would seem that ecological and geographical factors are primarily responsible for maintenance of the entity of species within the group.

The Uredinales that Parasitize Three-Awn Grasses. GEORGE B. CUMMINS, Purdue University.—From a study of extensive collections it is concluded that there are five species of *Puccinia* and two of *Uromyces* on the genus *Aristida*. Two species and four varieties are new. American collections on *Aristida adscensionis* are varietally distinct from the Old World *Puccinia aristidae* Tracy. *Uromyces seditiosus* Kern is a valid species distinct from *U. peckianus* Farl.

A New Direction for Plant Taxonomy and the Greene-Nieuwland Herbarium at the University of Notre Dame. MICHAEL H. LEVIN, University of Notre Dame.—The consolidation of the Greene-Nieuwland Herbarium in new quarters during July 1965 marked a significant step in the activation of an important university herbarium. The herbarium is now closely aligned with the objectives of the Ecology-Systematics Program, but not to the exclusion of research in the variety of disciplines which have denoted progress in plant taxonomy.

Plans for development and use, expansion, geographical specialization, and the current areas of research are discussed.

Botanists and other visitors are invited to inspect the herbarium which is presently located in Farley Hall.

A New Genus of the Actinoplanaceae, *Pilimelia* Gen. N., with a Description of Two Species, *Pilimelia terevasa* Sp. N., and *Pilimelia annulata* Sp. N. KANE, WILMA D., (Indiana State University, Terre Haute, Indiana, and The University of North Carolina, Chapel Hill, North Carolina).—Several keratinophilic organisms resembling the genus *Ampullariella* Couch (1964) differ sufficiently from *Ampullariella* in spore size and flagellation, sporangial wall breakdown, and in cultural characteristics to be described as a new genus. Studies of cultural characteristics, photomicrographs and drawings of morphological characteristics, and electron micrographs of flagellated sporangiospores are used to describe the new genus *Pilimelia.* Two distinct species, the type species *Pilimelia terevasa,* and *Pilimelia anulata,* are compared with similar organisms described by Karling (1954), Gaertner (1955), and Rothwell (1957), and these are all compared with *Ampullariella.* The two species described here were isolated from soil samples flooded with water and baited with human hair. Working cultures were maintained in sterile soilwater baited with hair. Pure cultures were maintained on Tryptone Glucose Yeast Extract Agar.

Indiana Plant Distribution Records, XIX. 1962-65.

JACK HUMBLES, Indiana University

Genera are listed in the order of their appearance in Deam's Flora of Indiana; species within each genus are in alphabetical order, and they are followed by the name of the county in which they were collected. Nomenclature is in accord with that used in Gray's Manual of Botany, 8 ed. 1950.

The specimens have been collected by the following collectors: Sue Allen, Robert Carnal, Ted and Zoe Chandik, Andre Clewell, Mark Fraker, Shelby Gerking, Don Gordon, Gustav Hall, Jane Holmes, R. Huff, Jack Humbles, Robert Johns, Henry Jones, Helen Link, C. D. Miles, David Peters, Ina Rea, Carolyn Richardson, Helene Starcs, Lola Stewart, Charles Sullender, and Paul Weatherwax.

Voucher specimens for all the new records are in the herbarium of Indiana University.

Taxonomic Entities

Typha angustifolia, Lagrange, Ripley. *Sparganium eurycarpum,* Brown. *Potamogeton amplifolius,* Lagrange. *P. berchtoldi,* Kosciusko. *P. crispus,* Lagrange, Kosciusko. *P. epihydrus,* Kosciusko. *P. foliosus,* Lagrange. *P. friesii,* Lagrange. *P. illinoensis,* Marshall. *P. praelongus,* Marshall, Lagrange. *P. richardsonii,* Kosciusko. *P. robbinsii,* Lagrange. *Zannichellia palustris* var. *major,* Kosciusko. *Sagittaria graminea,* Brown. *S. rigida,* Kosciusko. *Setaria viridis,* Brown. *Aegilops cylindrica,* Clinton. *Carex annectens,* Monroe. *C. cristatella,* Jackson. *C. grayii,* Monroe. *Symplocarpus foetidus,* Kosciusko. *Wolffia punctata,* Kosciusko. *Heteranthera dubia,* Lagrange.

Hemerocallis fulva, Ripley. *Erythronium albidum,* Gibson. *E. americanum,* Gibson, Fayette. *Trillium sessile,* Fayette. *Saururus cernuus,* Pike, Rush. *Salix nigra,* Pike. *Polygonum arifolium* var. *lentiforme,* Morgan. *Saponaria officinalis,* Pike. *Dicentra canadensis,* Fayette. *D. cucullaria,* Fayette. *Lepidium virginicum,* Ripley. *Aquilegia canadensis,* Kosciusko. *Delphinium ajacis,* Warrick. *Ranunculus trichophyllus,* Lagrange.

Cassia nictitans, Monroe. *Medicago sativa,* Ripley. *Melilotus officinalis,* Ripley. *Trifolium agrarium,* Monroe. *T. pratense,* Ripley. *Euphorbia corollata,* Brown. *Hypericum perforatum,* Vigo. *Viola eriocarpa,* Fayette. *Passiflora incarnata,* Vanderburgh. *Ludwigia palustris* var. *americana,* Lagrange. *Oenothera speciosa,* Brown. *Myriophyllum verticillatum,* Lagrange. *Pastinaca sativa,* Ripley. *Daucus carota,* Hancock. *Chimaphila maculata,* Owen. *Dodecatheon meadia,* Rush. *Asclepias syriaca,* Ripley. *A. verticillata,* Boone. *Myosotis scorpioides,* Monroe. *Verbena urticifolia* var. *leiocarpa,* Warrick. *Teucrium occidentale,* Monroe. *Nepeta cataria,* Ripley. *Lamium amplexicaule,* Warrick. *Pycnanthemum pilosum,* Lawrence.

Solanum dulcamara, Hamilton, Monroe, Ripley. *Datura stramonium*, Ripley. *Verbascum thapsus*, Ripley. *Utricularia cornuta*, Lagrange. *U. intermedia*, Lagrange, Kosciusko. *Plantago aristata*, Morgan. *P. lanceolata*, Hancock. *P. rugelii*, Hancock. *Mitchella repens*, Owen. *Lonicera japonica*, Brown. *Dipsacus sylvestris*, Brown. *Grindelia squarrosa*, Lawrence. *Chrysopsis villosa*, Monroe. *Erigeron canadensis*, Brown. *Antennaria neglecta*, Morgan. *Ambrosia artemisiifolia* var. *elatior*, Hancock. *Bidens bipinnata*, Johnson. *Galinsoga ciliata*, Hancock. *Helenium autumnale*, Hamilton. *H. nudiflorum*, Brown. *Anthemis cotula*, Pike, Ripley. *Senecio glabellus*, Owen. *Arctium minus*, Ripley. *Cirsium vulgare*, Ripley. *Cichorium intybus*, Madison, Hancock. *Pyrrhopappus carolinianus*, Pike.

Polygonum cuspidatum an Introduced Weed in Porter County

GAYTON C. MARKS, Valparaiso University

No mention is made of *Polygonum cuspidatum* in Deam's **Flora of Indiana** (2). Peattie describes no such species in his **Flora of the Indiana Dunes** (5). Many species of this group as described by Deam have been incorporated by subsequent authors into varieties or forms of more stable species. Generic name changes apparently have made some of Peattie's classification obsolete.

Such changes in nomenclature make identification and classification a bit confusing but in general this species and *P. saccharlense* (4) or *P. sachalinense* (3) are apparent introduced weeds from Asia. No traces of either by such specific names are found in the proceedings of the Indiana Academy of Science (6). It is thought there is a stand of the latter species two miles northwest of Valparaiso, but since it did not flower, positive identification was not made and this paper shall refer primarily to *P. cuspidatum.*

This species is commonly known as Mexican Bamboo or Japanese Knotweed. Two well established stands are located along the railroad and adjacent properties south of Valparaiso University. Presumably the railroad may have had some effect in seed dispersal.

Identification is least difficult in the **Manual of Vascular Plants of Northeastern United States and Adjacent Canada** (4). Gleason and Cronquist separate section Pleuropterus to which *P. cuspidatum* and *P. sacchalinense* belong from other groups in the following manner.

Section Avicularia has a small inflorescence, section Pleuropterus comparatively large. An obscure differentiation is the jointed leaves of Section Avicularia.

Pleuropterus is separated from Sections Bistorta, Persicaria, Echinocaulon, and Tovaria by possessing three outer sepals which are narrowly keeled. Finally *P. cuspidatum* and *P. sacchalinense* are separated from Tinaria because neither are trailing nor twining. *P. cuspidatum* possesses leaves which are broadly truncate at the base and may be separated from *P. sacchalinense* which has cordate leaves basally.

Other general features of *P. cuspidatum* are the stout sometimes branching stems, occasionally mottled, and reaching a length to three meters. The broadly ovate leaves (8-12cm x 12-15cm) are abruptly acuminate.

The inflorescence is a raceme originating from the upper axils and often branching freely to form panicles. The floret lacks petals but the five sepals are white to greenish white rendering a petal-like appearance. As previously stated the outer three are keeled and become winged in fruit providing a triangular achene.

The eight stamens have slender filaments and the three-parted stigmas are fringed. The pedicels are jointed at the summit. **Gray's Manual of Botany** (3) states it is dioecious although all specimens examined appeared to be monoclinous.

P. cuspidatum was probably introduced from Asia as an ornamental. Bailey describes a closely related form as cultivated for its decorative value (1).

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PSYCHOLOGY

Chairman: John F. Santos, University of Notre Dame

The Effects of Exploration and Test Frequency on Maze Learning[1, 2]

H. Heitman, Jr. and J. L. Albright, University of California (Davis) and Purdue University (Lafayette)

Introduction

Thorndike (4) demonstrated that common *Fundulus* with 6 to 8 trials a day took less time moving and hunting through a maze after a period of time with a food reinforcement placed in the shady half of an aquarium. Either one partition or three partitions with a single opening and of wood, glass, or wire construction were used. No quantitative data were reported.

Goldfish (*Carassius auratus*) were studied in a maze with one trial per day where the aquarium had two partitions each with one opening 2.5 cm. square (1). A 40-watt lamp was suspended over the maze aquarium, and food reinforcements cut in 4 mm. squares were used. Fish were maintained in individual pens and elapsed time was measured from the moment they were placed in the aquarium until they touched the reinforcement. The elapsed time was reduced quickly after 5 to 10 days. Partitions of wire mesh alone or wire mesh where the opening was banded with black 2.5 cm. wide were negotiated faster initially than ones of unpainted wood. After learning, however, the wooden or banded mesh partitions were passed more quickly than wire mesh ones. This led Churchill to conclude that sight was important in learning in goldfish.

Welty (5) allowed his goldfish to become accustomed to the maze aquarium with one screen partition and a simple opening 7.5 cm. in diameter by housing them in it for 7 days. After the preliminary period they were kept in the rear compartment. Goldfish were tested daily by opening the gate in the partition and simultaneously turning on a red light. As soon as a fish went through the opening, the food reinforcement (piece of earthworm) was placed in the appropriate part of the front compartment. A maximum reduction in elapsed time from the opening of the gate to the taking of the reinforcement was reached after 6 or 7 days.

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[1] Study undertaken at the N.S.F. Summer Institute in Animal Behavior, Michigan State University, East Lansing, Michigan, July 6-August 14, 1964.

[2] The authors express their gratitude to Drs. James Braddock and John King, Department of Zoology, Michigan State University for their advice and counsel during the course of these experiments. The assistance of Dr. John Santos, Department of Psychology, University of Notre Dame, is gratefully acknowledged.

The present experiment was devised to test the effects of exploration (familiarization) and frequency of testing on learning ability since prior work had not investigated these variables.

Materials and Methods

This experiment was designed as a 2 x 2 factorial trial testing aquarium familiarization versus naivete and one trial versus two trials per day.

The 40-liter aquarium was 51.2 x 26.9 cm., with the water height maintained at 18.0 cm. The partition was placed 34.0 cm. from the end where the reinforcement was to be placed. A 3.8 cm. red circle was painted on the end window equidistant between sides and 1.3 cm. from the bottom. The green plexiglass partition (0.3 cm. thick) had a 3.8 cm. hole in the same relative location as the red target. The aquarium was placed on a table by a window with a southern exposure and fluorescent lights were left on in the room during all tests. A cardboard shield was placed completely around the aquarium to a height of 20 cm.

Twelve goldfish (*Carassius auratus*) 4.5 to 6 cm. long were divided at random into individual gallon stock jars (15 cm. diameter with water height at 19 cm.) and to treatment. Each jar was aerated through a standard bluestone aerator. Three fish died during the familiarization (exploration) period reducing the test fish to nine. One-half of the fish were experienced to the aquarium for 7 days (omitting day 5) once daily by placing them individually in the tank. The partition was not in location in the water during this treatment. As the fish was placed in the water a portion of rolled oat was dropped in the opposite end beneath the red target. Elapsed time from placement in water to touching the reinforcement was measured. The remaining fish (naive group) were given an equivalent amount of rolled oat in the stock jar.

Whole rolled oats were used as a reinforcement. During the two periods the amount varied from ½ to 1 rolled oat with all fish being treated similarly on a given day. Fish being tested once daily were given another portion in the stock jar to approximately the amount received by those tested twice daily. The goldfish were purchased locally and knowledge of their prior feedings was not known. The fish were not starved and the daily oat reinforcement was their only food source.

At the end of the familiarization period the partition was inserted and the same procedure followed for six days on all fish except that half were run through the maze twice daily, one trial immediately after the other.

Results and Discussion

The five surviving fish during the familiarization phase learned quickly to swim from the release point to the reinforcement. On the first day the elapsed time averaged 3.7 minutes, but by the second day this was reduced to 0.8 minutes and the third day to 0.5 minutes. Over the remainder of this phase the average varied from 0.2 to 0.6 minutes.

The elapsed time during the six test days is presented in Table 1.

TABLE 1

Time from release to reinforcement—by day (summated mean values)

Day	Familiarized	Naive	Once Daily	Twice Daily
	Minutes			
1	4.3	12.2	6.0	9.2
2	2.7	4.1	4.7	2.4
3	0.9	3.4	3.0	1.5
4	0.5	0.8	0.5	0.7
5	1.1	3.5	3.6	1.4
6	1.4	0.8	0.6	1.5

The numbers of fish in each mean in Table 1 are 5, 4, 5, and 4, respectively. The data were analyzed statistically by the analysis of variance (3) as a 6 x 2 x 2 factorial trial with 6 days, familiarized or naive, and once daily or twice daily tested fish. The results are shown in Table 2.

TABLE 2

Analysis of variance of data from Table 1

Main Effect	df	Mean Square
Times daily (T)	1	1.41
Familiarized (F)	1	103.22*
Day of test (D)	5	90.66**
First Order Interactions		
TXF	1	49.30
TXD	5	13.89
FXD	5	28.51
Second Order Interaction		
TXFXD	5	2.81
Error	54	20.40

* Probability <0.05.
** Probability <0.01.

This indicates that differences due to previous familiarization with the test aquarium and day of test were statistically significant whereas number of trials per day was without effect. The Duncan multiple range test (2) indicated the difference in test day was between day 1 and subsequent days. The data did not appear to change this sharply after the first day.

Analysis of variance between elapsed times of familiarized and naive fish on a given day, or once daily versus twice daily trials on a given day, showed no significance. In the former case this was due to lack of numbers as indicated by the results of Table 2.

Elapsed time was also studied per trial as opposed to per day. This means that an attempt was made to equate the second trial on day 1 for the two times daily group to day 2 of the once daily fish, etc. The data (summated means) are given in Table 3.

TABLE 3

Time from release to reinforcement—by trial (summated mean values)

Trial	Familiarized	Naive	Once Daily	Twice Daily
	Minutes			
1	4.1	13.5	6.0	11.1
2	3.5	8.7	4.7	7.2
3	1.6	4.1	3.0	2.3
4	1.5	1.3	0.5	2.6
5	1.1	5.1	3.6	2.0
6	0.9	0.7	0.6	1.0

Analysis of variance was applied to the crude data again as a 6 x 2 x 2 factorial trial. No differences were statistically significant. Analysis of variance by days was carried out as well with negative results. When trials 1, 2 and 3 were combined and tested, the difference between familiarized and naive fish was statistically significant. A combination of days 4, 5 and 6 was not significant.

Testing fish twice daily as compared to once daily appeared to be ineffective whether considered as a comparison by days or by trials through the maze. It seems reasonable to project that the difference in testing (once versus twice daily) is an inadequate one, and another group should have been tested many times per day.

Prior familiarization with the test aquarium (even with the partition removed) was of importance particularly in the first few test days when elapsed time was changing relatively rapidly. After three days any difference had disappeared.

Elapsed time decreased over the test period as in the work of Churchill (1), Thorndike (4), and Welty (5). In this study with a limited number of fish the statistically significant decrease appeared between days 1 and 2. Larger numbers might well alter this observation and yield a smoother curve.

The experienced fish showed considerable exploratory behavior on test day 1 in contrast to the naive group. Elapsed time was also measured from the time the fish went through the partition hole until they touched the reinforcement. The familiarized and naive groups averaged 0.1 and 1.0 minutes, respectively, but this elapsed time was quite variable and due to a relatively few individual observations.

Summary

Twelve goldfish (*Carassius auratus*) 4.5 to 6 cm. long were randomly allotted in a 2 x 2 factorial study testing prior exploration with the test aquarium versus naivete and once versus twice daily testing. The nine surviving fish were placed in one end of an aquarium and required to swim about 17 cm. and pass through a 3.8 cm. hole in a plexiglass partition and swim an additional 34 cm. to a food reinforcement. Elapsed time in the aquarium was measured. The difference in elapsed time between familiarized and naive fish was statistically significant ($P < 0.05$). This difference was most pronounced during the first three days. Testing twice daily as compared to once daily was without statistical significance. The differences in elapsed time per day over a six-day test period were statistically highly significant ($P < 0.01$). The only statistically significant difference was between days 1 and 2, but an increase in the number of experimental fish would in all likelihood alter the shape of the response curve.

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The Influence of Developmental Level on Perceptual Learning

JOHN F. SANTOS and B. J. FARROW, University of Notre Dame

A few years ago in the Research Laboratories at the Menninger Foundation we inaugurated a series of experiments in which we employed an unusual stimulus which contained a word "embedded" between some apparently meaningless black shapes. This stimulus was chosen for a number of reasons. First of all, it has rather unusual figure-ground properties in that its more obvious characteristics are less meaningful than its less-obvious ones. Further, a good deal of pilot work had indicated that some subjects are able to perceive the word quickly, while others experience a great deal of difficulty in doing so even after being helped in "seeing" it. In addition, the restructing of the stimulus and the subsequent perception of the inconspicuous word (as we have come to call it) is almost invariably accompanied by a startle-like "aha" reaction which is easily observed, and subjects usually find the task interesting and amusing. Those subjects who quickly and strongly react to the black nonsense-like forms often have considerable difficulty in overcoming this orientation and in perceiving the inconspicuous word contained within the nonsense-like forms.

This stimulus thus seemed most appropriate for studying the attentional and perceptual processes, because of the unambiguous, meaningful stimulus that is potentially available along with the relatively meaningless configuration and the clear, sudden and dramatic shift that can occur from the perception of one to the other. This provides an excellent opportunity to manipulate and measure the relative facilitation or inhibition of perception that can be developed through prior experience.

Before presenting the study which is of primary concern in this report, some background research should be mentioned (5). In earlier experiments carried out by the present authors, different subjects were given one of several different training conditions after which they were presented the inconspicuous word that is shown in Figure 1. All subjects were asked to look at the inconspicuous word and to tell the experimenter what they saw. Figure 2 includes some examples of the training materials that were used in the initial studies.

One group of subjects had the task of identifying black nonsense forms on a white background by means of specified numbers, prior to being shown the inconspicuous word (Coding Training). The subject was instructed to label verbally each form according to the model at the top of the page and to work as rapidly and accurately as possible. Another group of subjects was given a task which required the formation of words from a series of white letters on a black background, arranged so that approximately sixty-five words could be formed (Word Training). Another group was required to practice the reversal of figure and ground, to observe visual illusions and to find specific figures within complex figures as rapidly as possible (Reversal Training). In addition to these basic groups, a number of control groups were employed in which white and black aspects of the materials were reversed. Still other

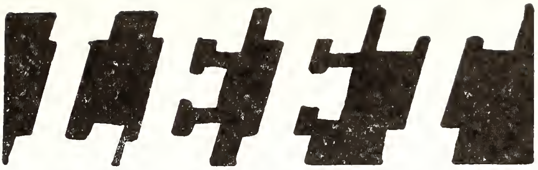

Figure 1. Inconspicuous word test stimulus used in the present experiment.

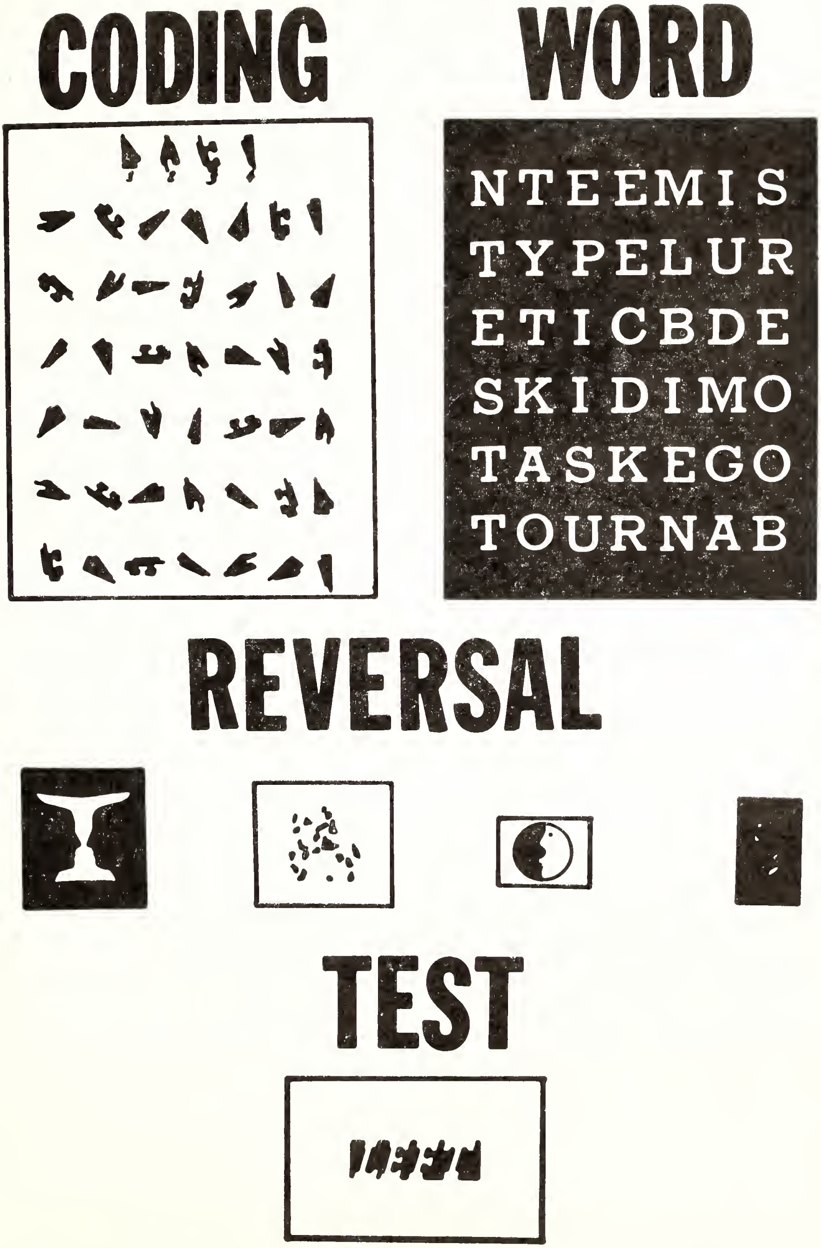

Figure 2. Samples of the training materials used in previous studies. Same reversal materials used in present investigation.

groups were given more training or a longer delay between training and exposure to the inconspicuous word than the original groups. A large number of male and female subjects were also tested to determine whether sex was an important variable in finding the inconspicuous word and an attempt was made to produce via instructions the effects that had been brought about through actual training and experience.

Briefly, reversal training was found to have a strong tendency to increase the probability that the inconspicuous word would be discovered rather quickly in a group of subjects, whereas the coding training inhibited its identification, and the word training tended to fall between the two. Significant sex differences were not found in any of the experiments but the differences were consistent and suggestive, especially in the reversal condition. Increasing the amount of reversal training increased the facilitory effects in finding the inconspicuous word and a delay of testing after reversal training allowed some of these effects to dissipate so that performance was hindered. The results of additional training and delayed testing were not quite so consistent for coding training but they were not significantly different from what was expected and predicted. Finally, it was found that verbal instructions could be used to bring about effects similar to those produced via training procedures. Thus, if the subject was told to look at the black nonsense forms, this tended to inhibit the location of the inconspicuous word, whereas if the subject was told to attend to the white areas, the results were quite similar to those obtained with the reversal condition.

These studies were carried out to secure some evidence relating to influence of learning on attention and perceptual selectivity. The findings indicated that some of the variables which have been found to be important for other types of learning can have an obvious and significant influence upon perceptual performance. Beyond this, however, we became interested in a number of other variables. One of these, which is the subject of our present paper, is the influence that age level might have upon perceptual flexibility. A number of different age groups separated by a number of years were used to represent somewhat different developmental levels that could be compared with respect to perceptual performance. These included subjects from elementary schools (ages 7-9), high schools (14-18), colleges (19-27), and a geriatric population (60-71). Subjects between the college and geriatric levels will soon be added but they have proven to be difficult to obtain.

Thus, for the age study the groups were made up of sixty-six elementary school subjects, forty-one high school subjects, seventy-seven college subjects, and thirty-nine geriatric subjects. All of these were exposed to the inconspicuous word and were asked simply to tell what they saw. They were allowed seven minutes to locate the word, and if they asked further questions or attempted to give up, they were urged to continue, without being given any clues as to what they were looking for. As indicated in Table I, on the first testing only three elementary school subjects (or about 4% of the group), nine high school subjects (or about 22% of the group), thirty-two college subjects (or about 42% of the group) and two geriatric subjects (or 5% of the group) were able to find the inconspicuous word. For the second phase of the experiment only those subjects were used who were not able to locate the inconspicuous word. These subjects were again brought into the experimental situation after delays ranging from seven to twenty-eight days, and were given reversal training with materials such as those shown in Figure 2, after which the test stimulus was again presented for seven minutes with the usual instructions. A few subjects were not available for the second session, but the drop-outs were relatively small in proportion to the total number that was eligible within each group.

TABLE 1

Detection of the inconspicuous word before and after reversal training

	Before Training			
	Success	Failure	N	% Successful
Elem.	3	63	66	4.5
H. S.	9	32	41	21.9
Col.	32	45	77	41.5
Ger.	2	37	39	5.1
	After Training			
	Success	Failure	N	% Successful
Elem.	11	49	61	18.3
H. S.	10	15	25	40.0
Col.	25	11	36	69.4
Ger.	17	20	37	45.9

The results of the original testing given in Table 1, were quite in keeping with our expectations, namely, that elementary school subjects and the geriatric group would show about the same level of performance with the inconspicuous word. In the case of the elementary subjects, it was reasoned that their perceptual processes had probably not yet developed a great deal of flexibility, whereas in the geriatric group, it seemed likely that some of the flexibility which had been present in earlier years would have been lost so that they would show perceptual rigidity. On the other hand, the high school students were expected to show greater flexibility than elementary or geriatric subjects but not quite as much as college students.

The results that were obtained from the four groups after reversal training were quite surprising and encouraging. Briefly, the expectations on retest were that since the geriatric subjects had already achieved a certain degree of perceptual flexibility, the reversal training might reinstate some of this, whereas for elementary subjects, who had not yet achieved any great flexibility, the reversal training would be too brief to produce any considerable change. It was anticipated that high school students would show more improvement following training than elementary or geriatric groups, and college subjects were expected to show the greatest improvement. Essentially, these expectations were confirmed by the results in Table I which were obtained after the reversal training with the exception of those for the geriatric group. Of the sixty-one returning elementary school subjects, eleven (or about 18%) located the inconspicuous word; of the twenty-five high school subjects, ten (or about 40%) found the inconspicuous word; of the thirty-six returning college subjects, twenty-five (or about 70%) found the inconspicuous word; and of the thirty-seven geriatric subjects seventeen (or about 45%) found the inconspicuous word.

While it is obvious that reversal training had a general tendency to improve performance in all groups, the change from the first to the second trial is especially dramatic for the geriatric subjects. From an initial level approximately the same as the elementary subjects, the geriatrics outdid even the high school subjects on retest. Of course, it is recognized that improvement within any given group depends upon initial level. That is, the higher the initial level the greater must be the change to show an impressive shift. Nevertheless, the relatively low initial levels of the geriatrics and the relatively high level following training suggests that some dormant but easily awakened potential for perceptual flexibility exists in these subjects that can be released with minimal effort and exercise.

The present findings will have to be followed up with further experiments to determine what is responsible for the initial differences and especially what changes so radically in the geriatric subjects following such a brief training experience. The information that is presently available indicates only that young children have difficulty in shifting from parts to the whole of a configuration (3) and that they tend to rely on immediate and passive perceptions until intellectual and perceptual growth changes this with succeeding years (1). Older subjects have likewise been found to have difficulty in ignoring irrelevant information while reacting to relevant stimuli (4) and like the very young they seem to be more "stimulus bound" and thus inflexible in their perceptual performance (2). Beyond providing some data for comparison of different age levels in perceptual efficiency, little has been done to suggest what underlying mechanisms are responsible for the differences or how performance can be improved at early ages or maintained at a higher level in older persons. At either age extreme knowledge of this sort would be useful in training as well as therapy.

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SOIL SCIENCE

Chairman: HELMUT KOHNKE, Purdue University

JAMES M. SMITH, Anderson College, was elected chairman for 1966

ABSTRACT

Earth Science in Secondary Schools. JAMES MITCHELL SMITH, Anderson College and Wright University.—Earth science in secondary schools is the subject of a nationwide program. An excellent source of information on this subject is the Earth Science Curriculum Project with offices at Boulder, Colorado. Far from the top in a national listing, Indiana has a token number of high schools offering courses in this subject. There is a well defined program in our teacher training universities to equip young people to teach earth science courses. The program is an expanding one with Dr. T. G. Perry, department of geology, Indiana University, one of the significant figures in this state.

Infrared Spectroscopy of Clay Mineral Systems[1]

J. L. AHLRICHS, J. R. RUSSELL, R. D. HARTER and R. A. WEISMILLER,
Purdue University

Infrared spectroscopy in the past few years has reached a place of importance in clay mineral studies comparable to that of x-ray diffraction. The two techniques are complementary with the former having the advantage that the material studied need not be crystalline. This new tool for clay mineral studies should rapidly add to an understanding of the minerology of Indiana soils which is needed in soil research, and also for the correct placement of Indiana's soils in the new soil classification system.

General Theory

The infrared energy from 2.5μ to 20μ wavelength is the particularly useful range for clay studies. The frequencies corresponding to these wavelengths are 4000 to 500 waves per centimeter (4000 cm^{-1} to 500 cm^{-1}). The most frequently used source of infrared radiation is a semiconducting filament or rare earth oxides heated electrically until it glows brightly. The desired frequencies of infrared energy are separated out by a prism or a grating.

The atoms in molecules and crystals are in a constant state of motion and have particular modes of vibration with respect to each other. The frequencies of these vibrations occur in the same range as infrared frequencies. The frequency of any vibrational mode of two or more atoms is dependent mainly on the mass of the atoms involved and the strength of the bonds between them. Thus each group of atoms in a molecule has its own characteristic vibrational frequency modes. If the vibration involves a dipole moment change which is not parallel with the incident beam, then the vibrating atoms are capable of absorbing infrared energy of the same frequency.

Infrared energy of a specific frequency will be absorbed when passing through a thin sample that has atoms with a vibrational mode of the same frequency. Thus a slow scanning of a sample with the infrared energy from 4000 cm^{-1} to 500 cm^{-1} will show a measured reduction in transmission whenever the instrument is measuring a frequency which is identical to the frequency of vibration of an atom group in the sample. Comparison of the measured frequencies with known frequencies of specific atom groups then gives information on the structure and composition of the sample. Stretching and bending modes of vibration are the most prominent frequencies observed. Combination and overtone frequencies occur less prominently.

Figure 1 shows a typical spectrum of montmorillonite over the 4000 cm^{-1} to 500 cm^{-1} frequency range. The first sharp decrease in

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[1] Purdue University, Agricultural Experiment Station, Journal Paper No. 2681.

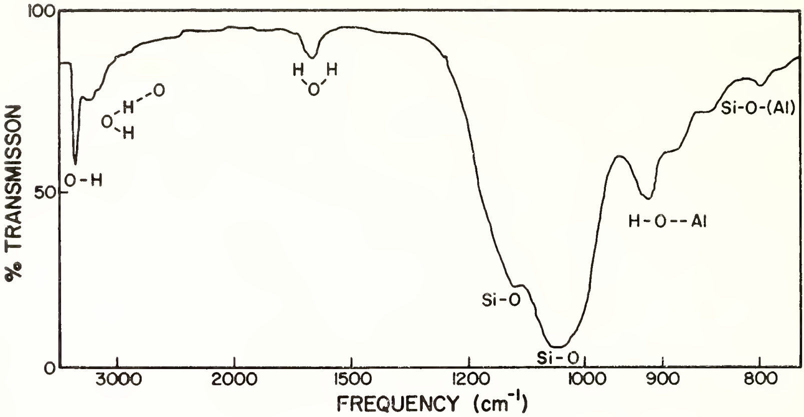

Figure 1. Infrared Spectrum of Montmorillonite Clay.

infrared transmission, i.e. the first absorption band, is at 3620 cm^{-1} This is the frequency at which hydroxyl groups in the clay crystal have a stretching vibration. The absorption band at about 3400 cm^{-1} is associated with hydroxyls in water. Their frequency of vibration is lower because they are involved in interaction, hydrogen bonds, with adjacent water molecules. This interaction results in weaker oxygen to hydrogen bonds and thus a lower frequency. The absorption band at 1630 cm^{-1} arises from an angle bending vibration of the two hydroxyl groups in water on the clay surface. The bands at lower frequencies are from various vibrations between silicon, oxygen, aluminum and hydroxyl groups of the crystal lattice as labeled.

Beers' law, which states that the log of the transmittance is proportional to concentration, holds well in infrared systems. Therefore, approximate concentrations of components in a sample can be made from the absorbance at characteristic frequencies of absorption for these components.

Shifts in the frequency of absorption of any atom group may occur if the environment of any of the atoms of the group changes. Association of one atom of a group with a force field such as that surrounding a highly polarizing cation like Al^{3+} will alter its electron distribution and thus the strength of its bond to the rest of the group. For example, the characteristic stretching frequencies will decrease if the bond is weakened and increase if the environmental change strengthens the bond. This is a useful tool in clay study.

Lastly, the stretching vibrational modes are particularly sensitive to orientation. If the change in dipole moment is parallel to the incident infrared beam, then no infrared energy of that frequency is absorbed. If the dipole moment change is perpendicular (normal) to the incident beam, maximal absorption will occur. This is also a useful tool in clay studies because clay crystals can be oriented in one plane by drying from suspension into flat surfaces, or may be randomly oriented by certain "pellet" techniques.

Discussion

In clay studies certain data are needed in order to identify and characterize the specimen: for example, is it triphormic (2:1) or diphormic (1:1); is it trioctahedral (3 out of 3 sites of the octahedral layer occupied by a structural cation) or dioctahedral (2 sites out of 3 occupied); what is the kind and amount of isomorphous substitution; what is the degree of hydration of the crystals; what is the nature of the crystal

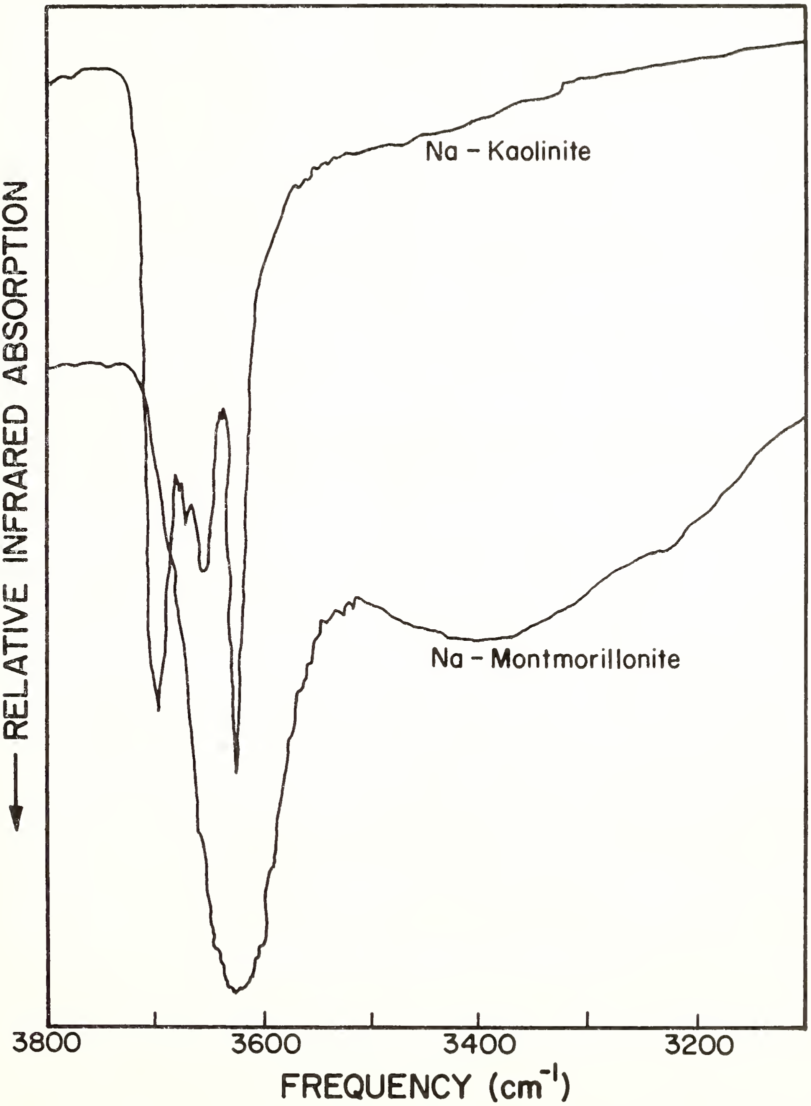

Figure 2. Infrared Spectra of the Hydroxyl Region of Triphormic Na-Montmorillonite and Diphormic Na-Kaolinite.

surfaces; what relative quantity of each component is present in clay mixtures; how prevalent are amorphous (non-crystalline) substances? Infrared spectra can give information on all of these.

Triphormic or Diphormic

Triphormic and diphormic minerals can be distinguished particularly by the hydroxyl stretching frequencies in the 3600 cm^{-1} region of a spectrum. Triphormic minerals, like micas and montmorillonite, have hydroxyls in one main environment associated with the octahedral cations located at the base of the hole in the tetrahedral surface of the clay. Since all are in nearly the same environment, all have nearly the same frequency and give one strong absorption band in the 3600 cm^{-1} region. The montmorillonite curve in figure 2 illustrates this. However, some of the hydroxyls in these triphormic minerals may have a slightly different frequency because of location near a site where some other cation has substituted for octahedral aluminum or tetrahedral silicon. Thus weak inflections on the main band are common.

Diphormic minerals of the kaolin group have a distinctive infrared absorption spectrum in the hydroxyl stretching region because they have a crystal surface composed of hydroxyl groups in addition to the hydroxyls common to the triphormic minerals. Thus kaolin shows four distinct hydroxyl absorption frequencies (figure 2). Variations of this pattern occur for other kaolin-group minerals.

Trioctahedral or Dioctahedral

Trioctahedral minerals can be readily distinguished from the dioctahedral forms. Dioctahedral minerals (pyrophyllite, montmorillonite, nontronite, kaolinite, etc.) give a different orientation affect than do the trioctahedral minerals (phlogopite, biotite, hectorite, etc.). Serratosa and Bradley (4) first illustrated this in a study of trioctahedral phlogopite. When the crystal was in the infrared beam with its 001 plane normal to the beam only a very weak absorption band was observed at 3710 cm^{-1}. The interpretation was that the O-H bond axis was parallel to the incident beam. The three octahedral sites are all occupied by Mg^{2+} which equally repel the hydrogen of the O-H group causing it to vibrate normal to the 001 plane. Decreasing the angle between the 001 surface and the incident infrared beam increases the hydroxyl absorption at 3710 cm^{-1}. The phlogopite pattern in figure 3 illustrates this strong increase in hydroxyl absorption with increasing angle. This orientation property is referred to as pleochroism.

The dioctahedral minerals have this same hydroxyl group but it is at a low angle to the 001 surface of the clay because only two of the three cations sites are occupied and thus repel the hydrogen toward the empty octahedral site. As the angle of an oriented sample of dioctahedral clay is decreased with respect to the incident infrared beam some hydroxyls are becoming more normal to the incident beam and increasing their absorption while others are becoming more parallel to the beam and decreasing their absorption. The net result is almost no change in absorption with such minerals as montmorillonite.

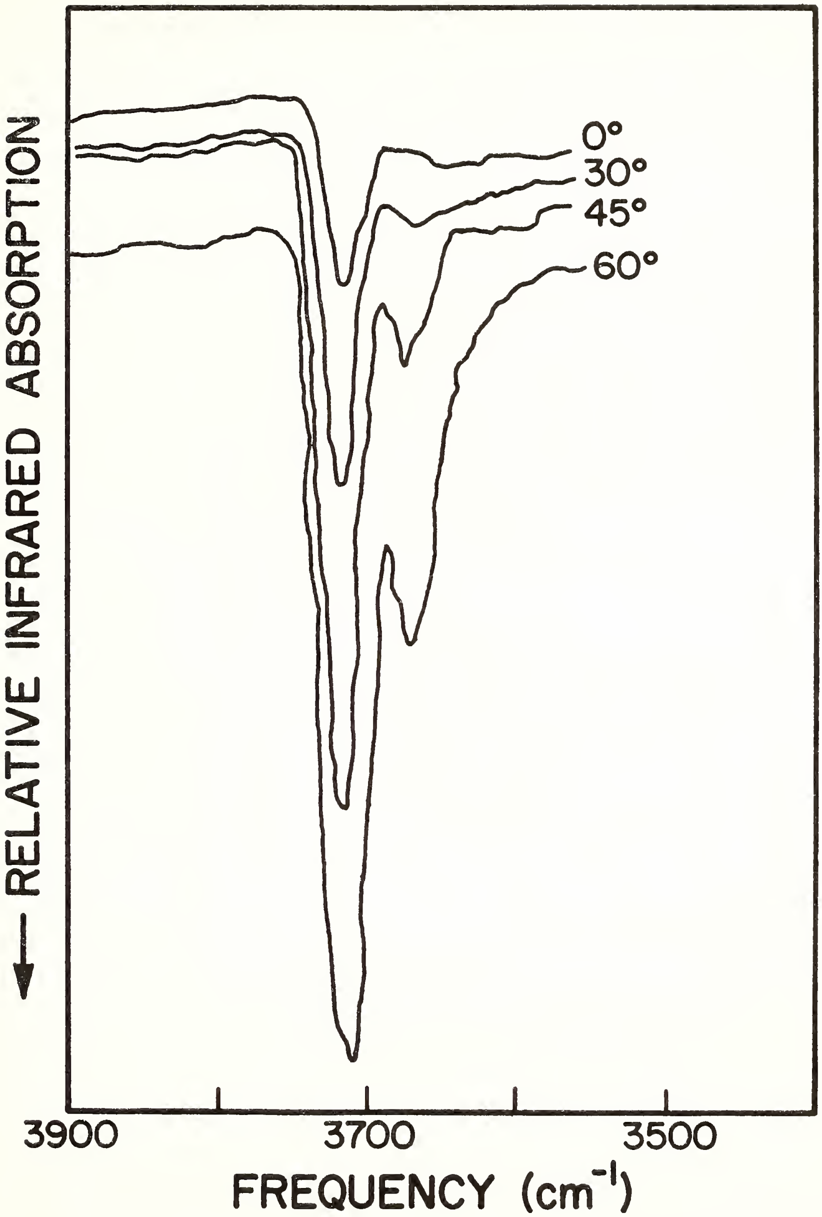

Figure 3. Pleochroic Effect of Phlogopite Hydroxyl Groups as the Angle of the Incident Infrared Beam to the 001 Axis Changes.

Isomorphous Substitution

Stubican and Roy (6) made controlled-composition, synthetic, clay minerals under high-temperature, high-pressure conditions to compare with natural materials. Talcs and pyrophyllites with substitutions of Ni^{2+} or Fe^{2+} for Mg, Ga^{3+} or Fe^{3+} for Al^{3+}, and Ge^{4+} for Si^{4+} enabled them to correlate absorption bands with particular atom groups in the structures. When the atom group was closely involved with the structural cation substituted it shifted its frequency as illustrated in figure 4 from their work. Note that, absorption at several frequencies in the 450 cm^{-1} to 950 cm^{-1} range are shifted greatly as the octahedral cation becomes Fe rather than Al. The most prominent shifts is of the 935 cm^{-1}, H-O—Al band of beidelilte to an 827 cm^{-1} H-O—Fe band in nontronite.

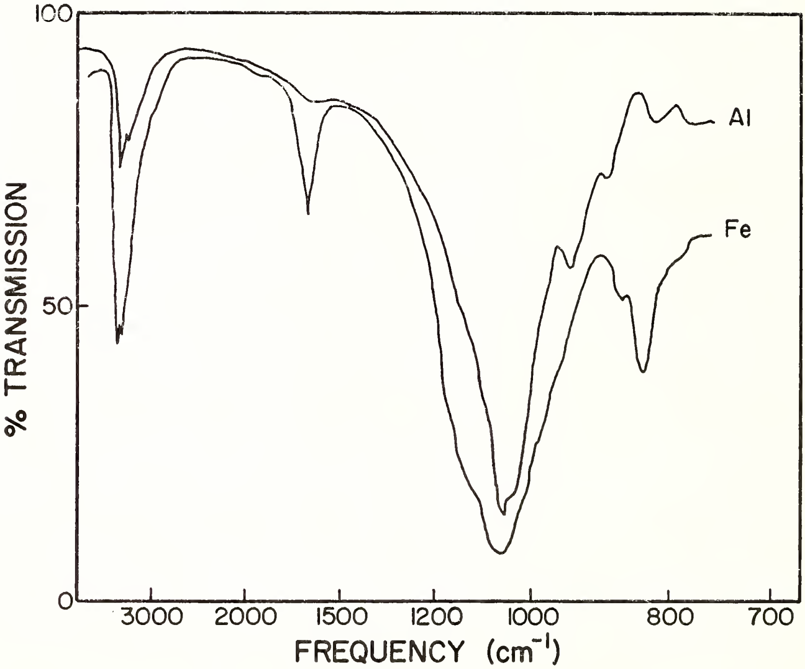

Figure 4. Spectra of Beidellite (Al) and Nontronite (Fe) from the Work of Stubican and Roy (6).

The location of the sites of substitution in the octahedral or tetrahedral layer is important in the characterization of a clay mineral. Stubican (5) with synthetics, and Tuddenham and Lyon (7) with natural micas found that the Si-O band in the 600 cm^{-1} to 750 cm^{-1} region diminished in intensity as Al—for—Si substitution occurred in the tetrahedral layer.

Hydration

The degree of hydration of a clay is characteristic of both the particular micelle and its exchangeable cations. Water gives a broad absorption band in the 3400 cm^{-1} range from hydroxyl stretching vibrations. The absorption band is very broad because of the many degrees of hydrogen bonding between the water molecules at any one instant. The stronger the hydrogen bond the lower the stretching frequency. The hydroxyl of water mainly appears at lower frequencies than the hydroxyls of the clay crystals. Water also has a bending mode at approximately 1640 cm^{-1} which is less affected by hydrogen bond strengths.

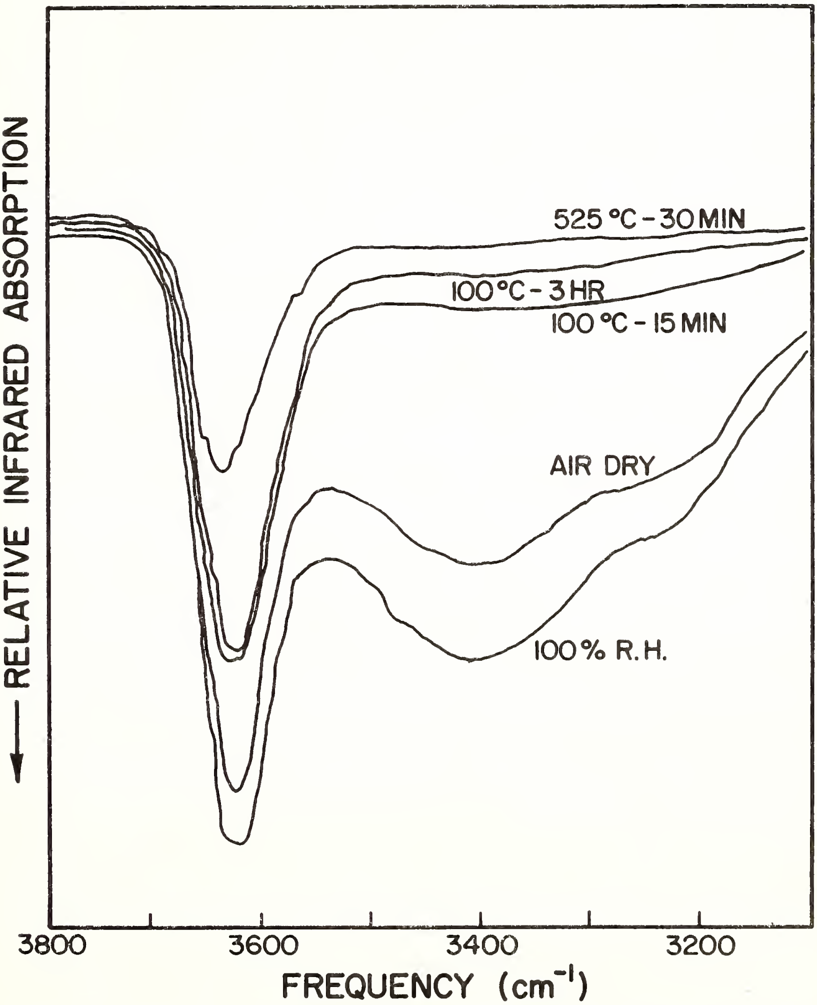

Figure 5. Dehydration and Dehydroxylation Effects on the Hydroxyl Region Spectrum of Montmorillonite.

The water band in the 3400 cm^{-1} region is characteristically strong in the highly hydrated montmorillonite type minerals and weak in the kaolin and micas which have very low hydration. Figure 5 shows how water removal from a montmorillonite decreases the 3400 cm^{-1} absorption. The absorption at 3620 cm^{-1} also has some contribution from water as evidenced by its decrease on drying. Drying at very high temperature (525° C) causes the crystal hydroxyls to be driven off as is seen by the sudden decrease in the 3620 cm^{-1} absorption. In more refined work Russell and Farmer (3) in recent studies have found that a relationship exists between the nature of the water bands from the first layers of water associating with a clay and the exchangeable cations around which they are oriented.

Surface Reactions

The character of the surfaces of the clay crystals is determinable from infrared spectral changes occurring when organic and inorganic compounds react with the surfaces. Ledoux and White (1) washed expanded kaolin with D_2O and found that a certain OH band changed to an OD band which occurs at a lower frequency because of the higher mass of the deuterium atom. This illustrated the ready exchangeability of surface hydroxyls in expanded kaolin as well as clarifying its infrared spectrum.

In other surface studies we have found that benzoic acid-sodium benzoate solutions dried with clay of the same suspension pH show an increase in the acid (COOH) band of the benzoic acid at 1700 cm^{-1} and a decrease in its 1550 cm^{-1} salt (COONa) band. The change in these two band intensities shows acidities of as much as 2 pH units more acid near the dry clay surface than exists in the clay-water suspensions.

Current infrared work with NH_3 and NH_4^+ and many organics is clarifying how clays interact with pesticides, fertilizers, soil conditioners and other soil additives.

Quantitative Analysis

Since the infrared spectral absorption appears to follow Beer's law the concentration of a compound should be proportional to the measured absorbance at a characteristic frequency for that compound. Current work in this laboratory shows this relationship to be true for kaolinite if the samples are randomly oriented to avoid pleochroic effects. Attempts are now being made to quantitatively determine kaolinite and other clays in mixtures.

Amorphous Clays

The importance of amorphous materials in soil has been recognized for many years. Methods for the investigation of these amorphous components, especially those of inorganic nature, are limited. However reliable results have been obtained by differential thermal analysis, surface area, electron microscopic, infrared absorption and x-ray diffraction techniques. The only application of the last technique to amorphous inorganic material lies in the recognition of ordering within the amorphous structure; completely amorphous systems show no x-ray diffraction.

Unlike diffraction techniques, infrared absorption methods of analysis do not require the sample under investigation to be ordered or crystalline; it is the masses of constituent atoms and ions, and the length and strength of bonds between them which control the absorption of infrared radiation. For this reason amorphous hydrated oxides of Al, Fe and Si have characteristic absorption infrared absorption spectra, and it is possible to observe well defined shifts in absorption bands resulting from substitution of Al for Si, for example in coprecipitated silica-alumina gels (3). Most important in this respect is the ability of infrared analysis to indicate the presence of an amorphous inorganic constituent in soil clay, the degree of polymerization of silica in the amorphous phase, and the possible major cation present.

Summary

Infrared spectra of clay mineral systems can separate trioctahedral from dioctahedral, triphormic from diphormic, and minerals with different degrees and types of isomorphous substitution. It can measure degree of hydration of a mineral, observe its surface character and interactions with organic and inorganic reactants, quantitize some clay systems, and indicate the prevalence and kind of amorphous substances present. It is an excellent new tool to complement the x-ray diffraction in clay mineral research.

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Yield Response of Small Grains to Nitrogen Fertilization[1]

Russell K. Stivers, Purdue University[2]

Nitrogen top-dressing rates studies on soft red winter wheat in Indiana have been reported by Stivers, et al. (4) and by Hodges and Stivers (2). These experiments used only one variety of wheat. Reports of fertilizer demonstrations conducted by the Purdue Extension Service (5, 3) indicate that only one variety was used in each trial.

The purposes of this study were first, to study yield responses of wheat and oats to rates of nitrogen fertilizer, and second, to study yield interactions between two different varieties of each crop and rates of nitrogen fertilizer.

METHODS AND PROCEDURES

Experiment 1

This experiment was conducted at two locations in 1964, and at two different locations in 1965. Locations used are numbers 1, 2, 3, and 4 described in Table 1. The previous corn crop at these locations had been fertilized with at least 100 pounds per acre of nitrogen. Some received more.

A split plot design with five main plots and two subplots was used at each location. Main plots were five rates of spring top-dressed nitrogen, and subplots were the two wheat varieties, Reed and Redcoat. Four replications were used.

Certified Reed and Redcoat wheat were seeded at the rate of approximately 7.5 pecks per acre at about the Hessian fly free date. This date was in late September in the northern part and in early October in the southern part of Indiana. The fertilization and planting were done with a 9-hole farm type grain drill. Approximately 15 pounds per acre of nitrogen along with phosphorus and potassium fertilizer were applied at planting. The amount of phosphorus and potassium fertilizer applied was as high or higher than recommendations based upon Purdue soil tests. Ammonium nitrate fertilizer was top-dressed by hand in late February or March.

Lodging was estimated just prior to harvest. Yields were determined by harvesting with a commercial farm combine. Harvested areas were approximately 120 feet by 5 feet. Yield data were adjusted to 14% moisture in the grain.

Experiment 2

This experiment was conducted at two locations in 1964 and at one location in 1965. Locations used were 2, 5, and 6 given in Table 1. The

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[1] Journal Paper No. 2666, Purdue University Agr. Exp. Sta.

[2] The author acknowledges the cooperation of Donald R. Griffith, John R. Hodges, and Monte W. Alderfer, and the help of N. T. Houghton, R. W. Carnahan, and R. D. Holstine in conducting this research.

TABLE 1
Description of Soils

					Purdue Soil Tests		
Location	Year	Farm and Address	Previous crop	Soil type	Soil pH	P Lbs. per A.	K Lbs. per A.
1	1964	R. W. Carnahan Edwardsport, Ind.	Corn	Iva silt loam	7.1	25 (Low)	61 (Very Low)
2	1964	H. Davis Forestry Farmland, Ind.	Corn	Morley silt loam	6.7	302 (Very High)	386 (Very High)
3	1965	R. D. Holstine Plainville, Ind.	Corn	Iona silt loam	6.2	74 (Medium)	118 (Low)
4	1965	H. Davis Forestry Farmland, Ind.	Corn	Blount silt loam	5.2	87 (High)	224 (High)
5	1964	Pinney Purdue Wanatah, Ind.	Corn	Runnymede loam	6.2	154 (Very High)	212 (High)
6	1965	Pinney Purdue Wanatah, Ind.	Corn	Runnymeed loam	6.8	113 (High)	210 (Medium)

crop used was spring oats. As in Experiment 1, the previous corn crop at these locations had been fertilized with at least 100 pounds per acre of nitrogen.

Experimental design and general procedure were approximately the same as for Experiment 1. The Runnymede locations were seeded on April 15, 1964, and on April 19, 1965. The Morley location was seeded May 8, 1965, after a long wet period. The rate of seeding used was approximately 9 pecks per acre. The five nitrogen rates were top-dressed immediately following planting. Subplots were the two spring oat varieties, Newton and Goodfield, in 1964, and they were Newton and Tippecanoe in 1965.

RESULTS AND DISCUSSION

Experiment 1

In two of the four wheat experiments, increasing rates of top-dressed nitrogen resulted in yield decreases (Table 2). One hundred twenty pounds per acre of nitrogen was associated with significantly depressed wheat yields over those obtained with 60 pounds on the Morley and Iona soil areas. Differences in lodging were too small to account for this difference. The bold face figures in Table 2 indicate the most profitable level of returns from nitrogen when nitrogen was valued at $.15 per pound and wheat was worth $1.30 per bushel.

TABLE 2

Relation of Rates of Top-Dressed Nitrogen to Yields of Wheat.

		Lbs. per A. of Top-Dressed Nitrogen					
Year	Soil	0	15	30	60	120	Lsd 5% Level
1964	Iva silt loam	53.1	**57.1**	56.2	55.5	53.8	Not Sig.
1964	Morley silt loam	**56.1**	55.0	56.6	56.3	52.7	2.4 bu.
1965	Iona silt loam	**57.7**	58.4	58.7	56.1	48.6	1.5 bu.
1965	Blount silt loam	**44.1**	45.8	44.2	46.5	47.7	Not Sig.

It is perplexing that there were no significant increases in yields in relation to increasing rates of top-dressed nitrogen. Demonstrations of the Purdue University Extension Service (5) indicate that about five bushels per acre increases in wheat yields can be expected for the first 25 pounds nitrogen top-dressed. All of the experiments listed in Table 2 followed high yielding corn heavily fertilized with nitrogen. There must have been a considerable amount of nitrogen carryover from the corn. Barber's work in Indiana (1) indicates that a residual value of 40 pounds per acre of nitrogen can be expected where 120 pounds was applied for corn.

There were no significant differences in yields between Reed and Redcoat wheat in 1964. However, in 1965, Redcoat wheat yielded more than Reed at both the Iona and the Blount soil locations. At the Blount location, winter killing of Reed was observed to be greater than that of Redcoat. At the Iona location Reed was observed to have more powdery mildew than Redcoat. This difference in disease resistance between the two varieties was, it is believed, partially responsible for their highly significant differing yield responses to increasing rates of top-dressed nitrogen (Table 3). With increasing rates of top-dressed nitrogen the decline in yield of Reed was linear. Yields of Redcoat increased up to 30 pounds per acre of nitrogen, and then they declined. Higher rates of nitrogen probably resulted in powdery mildew being worse on Reed, the more mildew susceptible variety.

TABLE 3

Interaction between Rates of Top-Dressed Nitrogen and Varieties of Wheat, Iona silt loam, 1965.

	Yields in Bu. per A. with These Lbs. per A. of Top-Dressed Nitrogen					
Variety	0	15	30	60	120	Av. Yield per A.
Reed	56.7	56.0	55.5	52.4	46.9	53.5
Redcoat	58.0	60.8	61.8	59.8	50.2	58.3

Experiment 2

Two of the three spring oat experiments had meaningful increases in yields as nitrogen fertilizer rates increased (Table 4). The extremely late date of seeding the third location, the Morley silt loam, could easily explain its lack of response. The bold face figures in Table 4 indicate the most profitable level of returns from nitrogen when nitrogen is valued at $.15 per pound and oats are worth $0.65 per bushel. Where there was a response to nitrogen, 30 pounds per acre resulted in the

TABLE 4

Yields of Spring Oats in Relation to Rates of Nitrogen Fertilizer

		Yields in Bu. per A. with These Lbs. per A. of Top-Dressed Nitrogen					
Year	Soil	0	15	30	60	120	Lsd 5% Level
1964	Runnymede loam	67.8	70.0	**76.6**	81.4	85.8	14.9 bu.
1964	Morley silt loam	**71.4**	74.5	73.1	69.5	67.3	Not Sig.
1965	Runnymede loam	69.8	76.6	**84.7**	87.1	89.3	9.0 bu.

highest returns from nitrogen fertilization. Except for the Morley soil, these responses are about the same or a little greater than the 16-year averages obtained in Purdue University Extension demonstrations (3).

May, with temperatures 15 degrees above normal during the first 8 days and with an average rainfall 2.5 inches below normal limited oat yields at the Runnymede location in 1964 (Table 5) to an average of about 76 bushels per acre. It is believed that these conditions also limited the yield response of oats to nitrogen. The resulting efficiency of nitrogen usage was poor.

Oat yields revealed a highly significant interaction between varieties and rates of nitrogen on the Runnymede loam in 1964 (Table 5). Newton oats yielded more than Goodfield oats at all levels of nitrogen except the highest, 120 pounds per acre. This difference was not related to lodging since there was none at this location. It appeared that Goodfield was able to respond more to higher rates of nitrogen than was Newton oats in this environment.

TABLE 5

Yields of Spring Oats in Relation to Rates of Nitrogen Fertilization, Runnymede loam, 1964

	Yields in Bu. per A. with These Lbs. per A. of Top-Dressed Nitrogen					
Variety	0	15	30	60	120	Av. Yield per A.
Newton	71.3	71.5	77.4	83.3	84.9	77.7
Goodfield	64.3	68.5	75.9	79.6	86.8	75.0

Summary

One hundred twenty pounds per acre of nitrogen fertilizer significantly depressed wheat yields over those obtained with 60 pounds in two of four experiments. Redcoat wheat yielded more than Reed wheat in the two 1965 experiments. A difference in disease resistance was given as a probable reason for the differing yield responses of these two wheat varieties to increasing rates of nitrogen at the Iona soil location in 1965.

In two of the three spring oat experiments yields increased up to 120 pounds per acre of nitrogen. However, dollar returns from the increased yield over the cost of nitrogen were greater at lower rates. At the Runnymede soil location in 1965 Goodfield oats responded to 120 pounds per acre of nitrogen with a higher yield than did Newton oats. At lower rates of nitrogen Newton oats had the higher yield.

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The Soil Survey in the Rural-Urban Complex

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Introduction

The high standard of living which is almost taken for granted by the American public stems in large measure from the plentiful supply of land resources with which we have been so richly endowed. Still, these resources are limited in contrast to human wants which appear limitless.

It was inevitable that our land use problems would multiply as population increased with its concomitant expanding public and private demands. Man, with his varying social, economic and personal tenants exerts his influence in the form of needs and wants. It is, however, a sad testimony that we have developed an environmental standard characterized by rural-urban sprawl, strip cities, clogged highways, and contaminated air and water. We may conquer "outer space" as we lose the battle for "open space." Secretary of Interior Stewart L. Udall (4) in his book **The Quiet Crisis** wrote "Each generation has its own rendezvous with the land, for despite our fee titles and claims of ownership, we are all brief tenants on this planet. By choice, or by default, we will carve out a land legacy for our heirs. We can misuse the land and diminish the usefulness of resources, or we can create a world in which physical affluence and affluence of the spirit go hand in hand."

It is in the urban and rural-urban fringe that the greatest land use conflicts confront us. There can be no quibbling with the need for housing, supermarkets, highways, and recreation areas. But we need to ask ourselves if we can afford the extravagant price we are paying in wastage of soil resources, to say nothing of the increased urban-associated costs, resulting from poorly planned or unplanned development. The problem is not one of an absolute shortage of land. Even with the projected population increases, and accepting our present helter-skelter pattern of development, it would be a long time in the future before an actual physical shortage of land forced adjustments in land use.

The total acreage in urban use[1] in 1959 was only 147 million acres and the 1980 projected use is 196 million acres (3). Clawson (1) estimates that the acreage in urban areas will total only 41 million acres by the year 2000, but that 80 percent or more of the total population will live in urban communities (255 million out of 310 million). The fact that urban land takes up such an insignificant amount of our total area (perhaps 2 percent by 2000) however, in no sense states the spatial significance of urban land resources. It is the land affected by the city that assumes importance. Water needs, for example, embrace entire river basins and exert a pronounced influence on land use over the entire area. Parks and recreation areas assume importance both within and around the city, and transportation systems require additional land. These problems do not stop at city boundaries or even at county lines. They frequently become regional if not national in character. Luther Gulick (2) sums it up as follows: "We need to create in the United States some broader basis of comprehensive thinking. While it is a wonderful thing to break bottlenecks by having one group build water systems, another group build highway systems, another one build bridges, and so on, it is also desirable to have these activities interrelated and that condition can be achieved only by using governmental units that cover a bigger regional area."

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[1] Includes urban and built-up areas and recreation and wildlife land.

The problem lies in the pattern of growth, or, perhaps it would be better to state, the lack of a pattern. One has only to look with open eyes to see our patchwork attempts. This paper, however, will not explore this aspect any further, but rather will attempt to discuss the importance of the soil survey and its interpretations in the rural-urban complex.

Status of the Soil Survey and Interpretations

The Soil Conservation Service, United States Department of Agriculture, has the principal Federal responsibility for making soil surveys. Its work is carried out cooperatively with the State Agricultural Experiment Stations and other Federal, State and local agencies. The work includes field and laboratory investigations, classification of the soils according to a national system, and publication in a standard series by the Department of Agriculture.

Soil surveys have been published for over 2000 counties and areas. Although many of these are now old, they still have limited use, especially for general planning. The more recently published soil surveys contain detailed soil maps and specific interpretations for many different uses. In addition, there are millions of acres of completed soil surveys on unpublished maps in soil and water conservation district offices which can be interpreted and used for planning purposes.

In Indiana, soil scientists and other specialists have developed tables giving brief descriptions of the major soils, their classification, and their measured and estimated physical and chemical properties. Engineering properties have also been tabulated. These tables provide extremely valuable information for users who need to know such things as permeability, available water capacity, frost potential, shrink swell potential, seasonable water table levels, location of flood plains, and depth to bedrock.

Recently, tables of "Interpretations of the Soils in Indiana for Rural and Urban Development" have been completed. These tables appraise the individual kinds of soil according to their relative suitability for residential development, light industry and commercial buildings, and roads and highways. These evaluations are expressed in terms of degree of soil limitations (slight, moderate, severe and very severe) and are predictions of the behavior of specific soils under stated conditions. Tables have been developed for "Interpretations of Engineering Properties of Soils—Nonagricultural (Urban) Uses," "Interpretations of Engineering Properties of Soil for Agricultural Uses," "Interpretations for Recreational Development" and several others of value in rural-urban fringe areas. The planner of today has tools available to help prevent many mistakes of the past and to aid in the planning and development of a rural-urban complex that more nearly meets society's expectations.

The literature contains many references to individual case histories documenting facts about housing developments that have been flooded, failure of septic tanks, foundation failures, and excessive costs associated with poorly located roads and facilities. When these conditions exist there is significant loss to the individual and the entire community.

An often overlooked fact is the amount of erosion occurring in the rural-urban fringe. Many believe that soil erosion and the resultant sedimentation problem around the metropolitan Washington, D. C. area must be numbered among the most serious problems. Recent studies by the Interstate Commission on the Potomac River Basin (5) point out that this area generated approximately a million tons of sediment in a single year, or almost one third of the total sediment discharge of the Potomac River. Studies by the commission also point out that sediment discharge in this basin varies from 21 to 2300 tons per square mile of drainage area per year depending on land use. Intensively cropped agricultural land experienced losses as high as 500 tons per square mile, but it was the areas undergoing urban development that reached the 2300-ton loss. Losses many times higher than this have occurred where entire areas have been bull-dozed and left exposed for long periods before construction was completed and vegetation established.

Rather than dwell on past mistakes, let us examine some of the specific types of interpretations that can be developed and how they can aid in shaping a better community. What can be done on a community-wide basis can of course be applied to a larger geographic area, and can also be pinpointed to the individual landowner. At the outset it should also be understood that consideration of the potentials and limitations of the soils is only one of the many interrelated considerations that must be evaluated, but it can be one of the most important and useful. This can be said for the rural-urban complex that is still only emerging on the drafting board, or the one that is experiencing current and often acute growing pains.

Transparent overlays of the detailed soil map, developed with soil interpretations for urban uses, are relatively easy to prepare and can be easily understood. A single rural-urban complex might find five or ten specific interpretations of special value, but the number that could be developed for specific problem solving would certainly number several times this figure.

The following interpretations on overlay maps are illustrative of how the basic facts and alternatives can be brought together for eventual decision by local interests.

Slope—An overlay indicating the degree of slope is frequently very valuable in developing an overall perspective of the area being studied. Slope breakdown into general groupings can be decided on the basis of available land, other limiting soil qualities, local decisions on maximum public road slopes to be permitted, etc. In Lake County, Indiana, for example, a tentative slope range of 0-2%, 2-6%, 6-12%, 12-18%, 18+% has been developed for urban purposes. In areas of steep topography an entirely different grouping might be appropriate.

Slope is particularly significant in areas that include soils that have a tendency to slip. Urban development frequently has been directed to the more picturesque hillside but the soil slope relationship has frequently been ignored. Shallow soils also present particular construction problems on the steeper slopes.

The slope map overlay quite frequently will indicate potential for natural beauty areas on sloping lands, areas where town or city forests may be developed or maintained, or perhaps a grassland agriculture located within the rural-urban complex. Even if the decision is to permit housing developments on the steeper slopes it will flag probable higher costs for construction and for maintenance.

The potential uses could be expanded at great length, but where topography does vary significantly it is an important consideration.

Drainage—Soil drainage is important in almost every use of soil. Overlays can be prepared which describe drainage in general terms such as droughty, well drained, poorly drained or very poorly drained. These may be adequate at the earliest stages of planning to indicate possible general patterns of use and growth. However, as more detail becomes needed it will be important to develop interpretations of more specific nature such as depth and frequency to seasonal water table, frost potential, percolation rate, shrink-swell potential and flooding hazard.

Suitability for Septic Tank Filter Fields—The development of an overlay indicating suitability for septic tank filter fields will necessarily consider several characteristics of soils that affect their suitability for absorbing waste from domestic sewage disposal systems. The major characteristics considered are soil permeability, percolation rate, ground water level, depth to bedrock, flooding hazard and slope. All soils in Indiana have been appraised for their relative suitability using the previously expressed degree of soil limitations (slight, moderate, severe, and very severe). These overlay maps will certainly figure very importantly in decisions involving housing, public buildings and size of lots.

Light Industry and Commercial Buildings—Overlays indicating suitability for light industry and commercial buildings can be developed based on considerations of several engineering characteristics. These would include soil texture, bearing capacity, shear strength, shrink-swell potential, compressibility, depth to bedrock, depth to water table and susceptibility to liquefaction and piping. All soils in Indiana have been appraised for this purpose.

These and many other overlays for specific purposes can be developed. It is a rewarding experience to see a pattern for future development emerge in the eyes of local planners as these overlays provide a sound basis for action.

Soil maps are made at a field scale of 4″ = 1 mile. The boundaries on maps between kinds of soil are not precise to the width of an ordinary house. The soils are examined consistently to depths of 4 to 6 feet. Thus, for heavy construction (roads, large buildings) and for specific on-site evaluation of a particular structure, the soil survey should be supplemented by more detailed and deeper examination at the site of the proposed structure.

Summary

The rural-urban complex includes the farmer, the suburbanite, the businessman and the industrialist. They all need land. The task of today's planner is to harmonize their demands in such a manner that an orderly and comprehensive plan results. The soil survey with its interpretations is one of the most important tools with which he has to work Properly utilized it can aid in arriving at a desirable spacial distribution of industrial, agricultural, residential and recreational development. It can help to identify areas well adapted to the requirements for open space. It can appraise suitability of soils for individual sewage disposal facilities, for building sites and development of transportation systems. It can be used by tax assessors as a basis for valuing land. It can, in fact, be important and useful in shaping and guiding the development of the entire rural-urban complex. We have the responsibility to see that all possible steps are taken to insure that the soil survey is used.

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Soil Information and Urban Planning

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The emphasis in recent years that has been given to the subject of urban growth is indicative of an awakening to the importance of rapid metropolitan expansion on the future of our nation. Some, in fact, have said that the complex problems of urban development constitute the greatest challenge of the twentieth century. Out of this interest and concern has developed town planning, city planning, urban planning, metropolitan area planning. Regardless of which title is used the meaning is the same even though many definitions of the terms can be found in the literature and a precise definition is probably impossible.

Planning is essentially oriented to the future. It is based on the premise that without community action some of the development within a metropolitan area may produce undesirable results. It recognizes that cities will develop and change without planning but that this development and change can be influenced in desired directions by means and costs which are acceptable and desirable. It attempts to conserve and develop the resources of an urban area to build a healthy, happy community.

The size of the urban growth problem and the companion need for wise planning, however, are not widely known or appreciated. Few people realize the magnitude of the current expansion of urban areas due to the large increase in the population of this country and the settlement of virtually all of this net growth in urban areas. One of the significant effects of this metropolitan expansion is the high national consumption of land for residential, industrial, commercial and transportation developments. The current estimated rate of use of land for such purposes is 3,000 acres per day (3). To satisfy this enormous appetite, thousands of acres of good agricultural land, areas essential for water supply, land vital for drainage-ways and floodplains, land containing scarce mineral resources, areas needed for increased recreational requirements, and hundreds of wet lands and woodlands are annually disappearing. It appears certain that huge metropolitan areas, such as the corridor from Boston to Washington, D.C., will soon be a reality.

It is to such growth as well as that in smaller areas and to associated problems that urban planning is directed. The attack on such problems demands a vast amount of information so that wise decisions on guiding metropolitan growth can be made. Because the development of land is a major result of metropolitan expansion, good planning includes land use planning which will result in wise land use development. The goal of such planning is to develop that land use for which each land area is best suited and which is needed by the community.

Such land use planning must recognize that land resources are limited and that misuse will only lead to severe environmental problems for the city. It also requires the collection and analysis of much information about each land resource area so that wise planning policies can be developed. Information needed includes data on water resources, recreational characteristics of areas, the location of scientific and historical sites, data on woodlands and wetlands, the location of natural fish and wildlife sites and information on soils.

The soils information required for urban planning is that which will assist the planner to determine the best land use to be made of any soil area while also considering the needs and desires of the inhabitants of the community. This includes information on how land areas are currently being used together with an appraisal of the success and value of such use and how they could best be used in an urban area.

Soil data needed for proper planning of land uses has received some study in recent years and one authority (1) has suggested that such information should permit preliminary assessment of:

"1. Engineering properties of soils as an aid in the development and selection of desirable spatial distribution patterns for residential, commercial, industrial, agricultural and recreational land use development.

"2. Agricultural and nonagricultural plant material properties of soils and natural wildlife relationships as an aid in the selection of desirable spatial distribution patterns for permanent agricultural and recreational greenbelts and open spaces.

"3. Suitability of soils for private on-site sewage disposal facilities, agricultural and urban drainage systems, foundations for buildings and structures, and water storage reservoirs and embankments as an aid in the planning and preliminary design of specific development proposals and in the application of such plan implementation devices as zoning, subdivision control, and official mapping.

"4. Engineering properties of soils as an aid in the selection of highway, railway, airport, pipeline, and other transportation facility location.

"5. Location of potential sources of sand, gravel, and other mineral resources."

In such a listing the engineering characteristics of soils receives emphasis as important information needed. This is so because in the development of land for many urban uses—highways, airports, structures, etc.—the soil is the most frequently used material in supporting these structures and is an important influence on the performance of the supported facility. The soil information required for urban planning, as outlined by Bauer (1) is as follows:

"1. Background information on the region, including physiography, geology, climate, cultural characteristics, and generalized soil areas.

"2. Soil formation and classification, including slope data.

"3. Soil descriptions, including typical profiles for each series and relationship of mapping units to series.

"4. Agricultural soil properties, including soil capabilities, crop yield estimates, and crop adaptation.

"5. Wildlife soil relationship properties, including capability to sustain various plant and animal species.

"6. Nonagricultural plant material soil relationships, including suitability for lawns, golf courses, playgrounds, parks and open space reservations.

"7. Water management properties, including identification of areas subject to flood hazard, stream overflow, ponding, and concentrated runoff.

"8. Engineering properties, including depth of major horizons, liquid limit, plastic limit, plasticity index, maximum dry density, optimum moisture content, mechanical analysis, AASHO and Unified classifications, percolation rate, bearing strength, shrink-swell ratio, pH, depth to water table, and estimated depth to bedrock if within approximately 20 feet of the ground surface."

Following the collection of such information, it can be utilized in the preparation of suitability maps for the area for several purposes. One such map might indicate by qualitative ratings the suitability of each area for development or redevelopment as residential, commercial industrial, recreational or open space. Characteristics of the soil, for example, would be important to development of an area for residential purposes with private sewage disposal facilities. Some areas with good internal drainage would be well suited to such development whereas other areas would certainly become troublesome or provide serious sanitary problems. It is not unusual to find large areas unsuitable for such development because of poor on-site sewage disposal characteristics of the soil. Other problems would be found associated with certain soils if they were used to support transportation systems. In both these examples as well as in many others prior knowledge of the engineering characteristics of soils could permit planning which would reduce the problems of development, permit a wise use of the available land, and provide for economical development and maintenance of the urban area.

The soil information desired will also permit an area-wide inventory of available construction materials for highway bases and fills, reservoir embankments and linings and other developments. Of major importance would be the availability of sands and gravels. Such data not only tells the planner where important materials are located but, depending on their availability in the area, provides him with excellent information for formulating policy for their conservation before they can be devoured by urban development.

One growing problem of many urban areas is the availability of usable water that can be supplied to inhabitants at an economical cost. Soil information can indicate suitable watershed areas which can be developed into reservoir areas to minimize this problem. The internal drainage characteristics of the soils, strength under conditions of saturation and susceptibility to erosion would be valuable data for such purposes.

The recreational needs of an urban area are great, especially as the amount of leisure time available to each inhabitant and his ability to move distances by automobile increases. The resulting requirements of each community are more golf courses, playgrounds, parks, and wildlife habitats (hunting and fishing preserves). All of these require soil that is economically capable of maintaining vegetation, thus making information on such characteristics of the soil important to proper urban planning.

Land suitability maps, previously mentioned, might be prepared for each of the important land uses: (1) agricultural, (2) large lot residential with private sewage facilities, (3) residential with public sewage facilities, (4) industrial, (5) recreational and (6) transportation routes. On such maps various symbols are used to indicate suitability of each land area by qualitative ratings, such as very good, fair, poor, and very poor. Such interpretative maps—prepared from an analysis of soil, topographic and other data—provide ready information needed by the planner to properly zone areas for land use development, layout transportation systems, allocate open spaces, plan water reservoirs, and establish recreational areas.

The benefits of having adequate information on the soils of an area, however, consist of more than the major one of conserving land by causing its development in the optimum manner. Other benefits include decreased costs of development and maintenance for the community and the developer. Land improperly used often results in high construction costs to correct for inadequate foundation characteristics, a situation which would have been eliminated by development in areas with better supporting characteristics. Maintenance costs of structures on inadequate foundations, street pavements for example, will also be high and would be minimized if constructed where soil characteristics were more desirable.

It is true, of course, that for many engineering uses of land, the characteristics of the sub-surface as well as the surface soils are required. Availability of data on subsurface soils for planning purposes is often available from geologic knowledge of the region, topography of the area, pedology of the area and from interpretation of aerial photographs. Of real value here would be improved correlation information between the soil information available in the agricultural soil surveys and the resulting pedological maps and the engineering characteristics of these soils. Considerable progress has been made in recent years in including such information with the agricultural soil maps but many of the soil maps of the counties of the state still need to have the engineering characteristics added.

To provide engineering soils information the Joint Highway Research Project at Purdue University initiated several years ago the production of county engineering soil maps. Maps for 35 of the 92 counties have now been completed and in addition numerous portions of other counties have been mapped for special purposes. The completed engineering soil maps at a scale of 1 inch = 1 mile are available to the public at a price of $2 per copy. These maps when used with the agricultural soil maps and geologic maps of the area can supply much of the information needed for wise land use planning and engineering facility planning.

In recent years an engineering characteristics section has been added to the agricultural soil maps to make them more complete. This has proved most valuable. Unfortunately neither such maps nor other engineering soil information are available for many counties in Indiana. The number of such counties, however, is decreasing each year and hopefully will be entirely reduced to zero within the next several years.

Soil is probably our most important resource. The few inches of soil developed over time supports humanity. Is man capable of conserving it? Experience of the past, as suggested by Walter Havighurst (2), does not particularly assure us of man's efforts. As he tells it:

"In 1823 a little Norwegian wanderer, named Cleng Peerson, walked overland from New York to the western territories. At Chicago he turned north. For six days he printed his steps in the blank sands of Lake Michigan. At evening he boiled his kettle at the lake's edge. He slept under the soothing drones of water. At the site of Milwaukee (three log huts, one of them empty) he found a tall man, naked to the waist, beside a cabin hung with traps and snowshoes.

"What will I find if I continue north from here?" Cleng Peerson asked.

Solomon Juneau was a fur trader. He knew the great twilight of the forests.

"Woods to the world's end," he replied.

"It was literally true. Woods for 600 miles. In that day six-sevenths of Wisconsin was forest. Two-thirds of Minnesota was forest. The upper peninsula of Michigan was all forest. And the forest began beyond Lake Superior, stretching away toward Hudson Bay. A country as big as France and every mile of it mysterious with forest twilight and haunted with the sound of running water . . . cedar, hemlock, tamarack and pine. A forest rich and vast enough for the needs of a nation forever.

"Try to find that forest now. . . .

"The timber cruisers came, walked through the country. . . . Behind them came the lumber kings and the great corporations. They logged off the forest in a furious assault. "Come and get it" was the cry of the lumber camp. . . . "Come and get it" was the slogan of the corporations. . . .

"How did the big corporations get hold of all of the timber? There was the Stone and Timber Act of Congress, designed to safeguard national resources. But the corporations found the loopholes, and they got the timber.

"Following the mining of timber came the fires that swept not only the fallen timber but the seeds as well . . . so there was no second growth. Conservation of this forest preserve came 50 years too late."

Will our soil resource experience the same fate from the demands of urban growth for the development of thousands of acres each day? A real hope exists that waste of this resource will be minimized if we utilize the techniques and philosophy of urban planning to develop community policies for urban development which uses land for desirable and unfilled urban purposes. Good planning, however, requires a lot of information of many kinds, including information on soils, and its utilization in the planning process. This is where each of us can enter the battle, can assist with urban planning.

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Soils Affecting Urban Uses—A Teaching Program

HARRY M. GALLOWAY and ALBERT J. BEAVER, Purdue University

Agricultural workers have recognized for a long time that soils vary greatly in their suitability for crop production. Factors like natural fertility, fertilizer response, texture, slope, drainage and erosion all affect soil productivity.

Soil characteristics also affect the use to which soils are subjected near growing cities. Soil bearing strength, frost heave potential, permeability, compactibility, shear strength and reaction are important characteristics which affect many urban uses of soils. Because of the variability in these properties and others, soils differ in their suitability for building sites, highway subgrade, parks, airports and other uses.

Both the rapid population growth in numbers and its increasing mobility have placed more people in situations where soil conditions directly affect them. This is especially true in rural-urban fringe areas where people are moving to enjoy country living.

A lack of appreciation for soil differences by many users has resulted in many costly mistakes. These mistakes are due to the use of soils for purposes for which they are unsuited. Many problems have arisen simply because people do not realize that soils are different. They may see homes built successfully in an area near which they would like to live. Yet when they attempt to build a new home themselves in the nearby area, they may find, too late, that those soils are unstable, have a high water table or won't absorb the effluent from a septic tank. Some persons learn to their sorrow that their new home is on a flood plain which overflows occasionally. Builders may encounter hardrock during construction which is expensive to remove. Later the owner may find that this same rock or in other cases hardpan subsoil layers cause seepage during wet seasons. These may keep basements wet or make it difficult to grow lawns and shrubbery. Mistakes like these can be avoided by people who realize that soil characteristics influence the suitability of soils for urban uses.

Because farmers are close to the land and work on or dig into the soil, they are usually well aware that soils are quite different from place to place. Educational efforts by the Cooperative Extension Service, Soil Conservation Service and other agencies have also helped farmers understand soils. Today many farmers use soil maps, which define areas of different soils as basic tools in developing their management plans.

Unlike the farmer, most urban people do not have sufficient contact with the soil to develop an appreciation of how soil features may affect its use. While many depend upon the judgment of architects, engineers, and developers as they plan new projects, others do not seek sound advice. Some are misled by developers who do not know about adverse conditions. Yet, there is a wealth of knowledge uncovered by soil and geologic surveys which could help urban people with soil problems just as it has helped farmers.

Awareness Phase

A few years ago in Indiana, soil specialists began to promote wider understanding of how soils affect our urban people. Through our county extension agents and our Soil Conservation Service workers we have begun to reach out to groups with whom we have not usually contacted in the past. We have developed contacts with state and county health workers, county planning commissions, the State Division of Community Planning, builder and developer associations, watershed sponsoring groups, highway departments and many public officials. They have been shown how soils differ and how soils maps can clearly locate these differences. Some groups have been taught how to use soil maps and other geologic and water information that is available and of value to them. Special schools have been conducted in 20 counties to help people understand soil and water resources as they affect community development. This initial work, which can be called the "awareness" phase, has involved teaching urban people how soils knowledge can be useful. This "awareness phase" is well along in Indiana and in certain other states. Now we approach an "action phase" which involves the teaching and dissemination of soils information in such forms that people can use it.

Soil Teaching Techniques

Many of the techniques for teaching and conducting such "action programs" can be adapted from methods used in teaching farm people soil information. Effective visual aids are needed to illustrate soils and soil principles.

Monoliths (trays of natural soil sections to a 4-foot depth) and colored soil slides with brief, clear labelling are proven devices for use with urban audiences. Soil descriptions pointing out the features of interest to the audience need to be brief, concise and graphic. Block diagrams help greatly when used to relate soils to parent material, topography and location in the landscape. These techniques all have been used successfully for years with farm groups and work well for both indoor meetings and field trips (1).

Soil maps and reports contain a wealth of detailed information helpful to urban users, however, because of their great amount of detail these can be confusing to the average user. To help them understand these detailed reports, soil association maps, which show geographic groups of closely related soils, are used to consolidate the detail. Overhead projection of these specially prepared soil association maps works well when addressing large audiences indoors. On soil field trips, soil association maps help people relate the soils and soil features seen to other areas not observed due to lack of time.

Rapport can often be established with an audience early in a meeting by relating soil areas delineated on soil maps to familiar local landmarks like schools, highway intersections, parks, quarries, lakes and streams. Interesting soil features recounted about one or two soils in each soil association also helps interest the audience, because each person will have some knowledge of the soils and their properties found in their locality.

To place modern surveys into more immediate use, interpretations have been developed for certain urban uses concurrent with field mapping. As these are published, generally as brief reports, they become guides for using soil survey field sheets as they are completed. Such reports are taken to public meetings and explained to representatives of various groups who would benefit from a knowledge of soils in their work. Special soil survey use exercises are employed to teach each person how to read a soil map and how to interpret the soils information in the report.

In some counties copies of each soil survey field sheet are purchased by a county official as they are completed. Individuals also buy them for their own use. Where field sheets are being used locally for city or county planning, brief "interim" reports such as the Munster report have been prepared and financed with local funds. These "interim" reports allow use of soil data and soil maps obtained early in the survey some five years prior to the availability of the published soil survey report. Thus the needs of those groups wanting to use soils information can be fulfilled as the survey progresses.

Surveys in Comprehensive Planning

Greatest interest in using soil surveys has come from counties organizing planning commissions and those beginning comprehensive planning. For example, Lake County, Indiana employs a soil scientist in the Cooperative Extension Office to interpret soil maps being made by the progressive soil survey. He works closely with the consulting planners who are preparing a revised county master plan and also with all persons or groups requesting special soils help. He conducts an aggressive educational program which includes the preparation of soil maps and brochures for city officials interested in planning the future growth of their city.

Soil areas on a detailed soil map when interpreted and shown on a suitability map for a single purpose act is ready information for planners. These maps prepared as colored overlays may show three to five classes of suitability for a particular use such as residences needing septic disposal systems. Planners find maps such as these are very useful in zoning areas most adapted for particular uses.

Soil Interpretations

During the course of soil surveys the soil scientists are consulted for information and advice on urban land use by planning commissions, sanitarians, highway engineers and others. Until now most of this advice has been based on the experience and opinion of the soil scientist because no uniform suitability classification exists for each of the many potential uses of soils.

A soil sampling and testing project, which provides test values used in making soil interpretations, is being conducted in cooperation with the Bureau of Public Roads and the Purdue Joint Highway Research Project. This sampling and testing will continue until topsoil, subsoil and parent materials of all important Indiana soil series have been studied.

The Soil Conservation Service and Cooperative Extension Service in Indiana have begun preparing tables of soils interpretations for many purposes. These tables will act as references of soils data for easier use and serve as guides to keep soil suitability ratings uniform.

To date suitability interpretation of the major soils in Indiana have been prepared for the following uses:

1. Estimated physical and chemical properties.
2. Engineering test data for about 65 soil types.
3. Interpretations for use in rural and urban developments.
4. Interpretations of engineering properties for nonagricultural (urban) uses.
5. Interpretations of engineering properties for agricultural uses.
6. Interpretations for six types of outdoor recreational uses.
7. Interpretations for wildlife habitat and kinds of wildlife.
8. Predicted yields of soils under two levels of management.

In these tables soils are rated as having a slight, moderate, severe, or very severe degree of hazard for a potential use. Factors causing the limitations are also given.

All of these interpretations have been prepared in limited quantities for use by technicians. While wide distribution of these tables is not anticipated they will give the background information necessary for the preparation of brief "interim" reports covering soil areas near expanding cities, townships or counties.

Demonstrations Explain Principles

In teaching people about soils it seems far more valuable to explain principles which people can think about and apply than to describe specific features they can read elsewhere. Discussion of principles of water movement and storage in soils appear to be most important since water is involved in most of our urban soil problems. Four simple but effective demonstrations illustrating principles of soil and water movement we have used successfully are outlined below.

1. Soil infiltration and permeability.

Glass columns filled with soils of the same texture but differing in degree of natural granulation and organic matter content are placed near each other. A known quantity of water is added to each column and time is recorded. The audience observes the rate of infiltration and percolation of the water and notes the decrease in percolation and gradual sealing of the poorly granulated soil. In discussion, factors affecting infiltration and percolation rates such as grass cover, mulches, soil texture and structural stability can be pointed out. These can be related to soil erodibility, water runoff, and soil drainage.

2. Effect of limiting layers in soils.

Two damp synthetic sponges with medium size pores placed back to back are held horizontally before the audience while water is joured on the sponges. The amount of water absorbed is recorded.

Water is squeezed out of the sponges and a piece of blotter paper slightly larger than the sponges is placed on the top sponge leaving a lip extending over one end. Water is poured slowly on the blotter and the amount absorbed by the blotter and sponges is recorded. The audience sees that only a small amount of water is absorbed before it begins to run off the edge of the blotter compared to that absorbed by the sponges alone. This illustrates the effect of pore size on infiltration with the blotter acting like a fine pored, puddled surface or a severely compacted one.

Repeat above sequence with the blotter between the sponges. Water is absorbed quickly by the top sponge but very little enters the lower sponge. This illustrates the effect of natural soil pans, plow pans or severely compacted layers found under many lawns, playgrounds and athletic fields resulting from poor construction practices.

3. Hydraulic head and underground water movement.

The simplest illustration of hydraulic head involves wetting a sponge, held in a horizontal position, until water just begins to drop from the bottom. Then when the sponge is turned in a vertical position water will quickly run out the bottom. The vertical dimension which is 3 to 4 times the thickness of the sponge can be compared to an increase in hydraulic head. Thus the audience can see that the same amount of water in a narrow vertical column has a greater "head" than when in a wide but shallow column.

A more sophisticated approach involves using soils of different textures in a system where water in funnels is connected by plastic tubing to other funnels containing the soil. The head is adjusted by raising the water filled funnels so the water reservoir exerts pressure on the soil. The time needed for the water to reach equilibrium on each side is a function of soil permeability which is related to soil texture, structure and porosity.

This demonstration can be used to develop an understanding of how ponding around a foundation will result in faster penetration of water into a soil due to an increase in hydraulic head. This results in greater pressures on basement walls and floors where soils are porous and sandy than where the soils are fine pored such as in silts or clays. Also, it can help explain the adverse effects of high water tables on basements in soils of different textures.

4. Soil capillarity and water rise.

Small damp sponges of different pore sizes are placed vertically in a shallow dish of colored water and the time is noted for the water to rise to their tops. When started early in a meeting, the fine pored sponge may wet completely by the middle of the meeting whereas the coarser pored sponge may wet only part way. This illustrates the principles of capillary rise such as occurs in fine textured soils and rocks.

A system of water in a porous clay cup sealed to a mercury manometer will illustrate the suction forces exerted by dry soil for moisture. The water filled cup is placed in sieved silt loam soil and the manometer is held at the same height. The cup will release water to the soil which exerts a suction on the mercury reservoir causing mercury to rise in a capillary tube. When started early in a meeting, the mercury will rise 10 to 15 inches by the end and evidence of wet soil can be observed through the glass jar containing the soil.

These demonstrations show how water moves from a moist zone to a dry zone through fine pores with a suction force exceeding the force of gravity. This principle can be applied to illustrate the height water will rise above a water table depending on soil texture. The need for a vapor barrier in basement construction and the reason builders can plan basements in some soils and not in others is easier to explain by using this demonstration.

What Lies Ahead?

The foregoing has told of the situation in Indiana which makes soil surveys valuable. It describes the nature of teaching programs used thus far with urban audiences. Much more experience is needed before we will perfect techniques needed to adequately reach this new audience with its many interests and diverse backgrounds. Better methods must be developed to reach these people who are not accustomed to dealing with the Cooperative Extension and Soil Conservation Service. More printed material about soils must be developed which can be distributed by agencies such as state and local health boards and planning commissions. Soils training needs to be given to the many individuals who have regulatory or inspection functions so they can understand soil principles and make intelligent recommendations. Magazine and newspaper articles will continue to call attention to soils problems and possible solutions. Demonstrations need to be developed for use in meetings, to illustrate important soil properties in addition to those involving water.

If this were to be rewritten 10 years hence, much more experience could be related. The methods of reaching people may be different at that time. However, no matter how completely planning commissions, engineers and developers use soil facts to make better decisions, we can be sure of one thing. That is, teaching simple fundamental facts about soils and how to use knowledge collected by soil surveys will still be high priority items as we work with the urban audiences of the future. Many more people will be available for these audiences. They will have needs just as urban people do today. The job ahead is a very large one.

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ZOOLOGY

Chairman: William R. Eberly, Manchester College

Russell E. Mumford, Purdue University, was elected chairman for 1966

ABSTRACTS

A Preliminary List of the Fishes of Tippecanoe County, Indiana. Don C. Erman and Russell E. Mumford, Utah State University and Purdue University.—Since 1958, numerous species of fishes have been added to the Tippecanoe County list, as the result of more extensive collecting and improved collecting methods. The total number of fishes known from the county is 66, but this list is incomplete.

Fishes of Vigo County, Indiana. John O. Whitaker, Jr. and Dale C. Wallace, Indiana State University.—A study of the occurrence, distribution and ecology of the fishes of Vigo County, Indiana was begun in November of 1962. The fishes were collected primarily by seining. Some collections were made in the Wabash River and in deeper waters with the aid of a shocker boat from the Indiana Department of Conservation. To date 252 collections have been made. Ninety-four different species of fish have been taken and twenty-four of these are new records for the county. Eight of the species which were reported by Jenkins[1] Blatchley,[2] and/or Gerking[3] have not been taken during this study. A total of 102 species are now known for the county.

A list of the new records for the county follows: *Icthyomyzon unicuspis, Lampetra lamottei, Hiodon tergisus, Alosa chrysochloris, Carpiodes carpio, Moxostoma anisurum, Moxostoma breviceps, Moxostoma valenciennesi, Cyprinus carpio, Carassius auratus, Hybopsis x-punctatus, Rhinichthys atratulus, Chrosomus erythrogaster, Pimephales promelas, Noturus eleutherus, Noturus flavus, Aphredoderus sayanus, Percina sciera, Etheostoma chlorosomum, Etheostoma spectabile, Etheostoma gracile, Micropterus punctulatus, Chaenobryttus coronarius* and *Lepomis microlophus.*

The species reported by previous investigators but not seen during this study are: *Icthyomyzon bdellium, Acipenser fulvescens, Cycleptus elongatus, Hybopsis amblyops, Notropis whipplii, Morone interrupta, Stizostedian vitreum,* and *Percina shumardi.*

Ecological information from this study will be further examined.

Amphibians and Reptiles of Vigo County, Indiana. David Rubin, Indiana State University.—Forty-three species of amphibians and reptiles were collected in Vigo County from 1963 to 1965. Three of these, *Plethodon dorsalis, Scaphiopus holbrooki,* and *Eumeces laticeps,* are new county records bringing to 54 (51 species considered to be valid were recorded by W. S. Blatchley in the 1890's) the number of amphibians and reptiles known to occur or to have recently occurred in Vigo County. Fourteen are salamanders: *Necturus maculosus, Siren intermedia, Ambystoma jeffersonianum, Ambystoma maculatum, Ambystoma opacum, Ambystoma texanum, Ambystoma tigrinum, Notophthalmus viridescens, Plethodon cinereus, Plethodon dorsalis, Plethodon glutinosus, Hemidactylium scutatum, Eurycea bislineata, Eurycea longicauda.* Twelve are frogs: *Scaphiopus holbrooki, Bufo woodhousei, Acris crepitans, Hyla crucifer, Hyla versicolor, Pseudacris triseriata, Rana areolata, Rana catesbeiana, Rana clamitans, Rana sylvatica, Rana pipiens, Rana palustris.* Nine are turtles: *Chelydra serpentina, Sternothaerus odoratus, Terrapene carolina, Graptemys geographica, Graptemys pseudogeographica, Chrysemys picta, Pseudemys scripta, Trionyx ferox, Trionyx muticus.* Two are lizards: *Eumeces fasciatus, Eumeces laticeps.* Seventeen are snakes: *Natrix septemvittata, Natrix kirtlandi, Natrix rhombifera, Natrix sipedon, Storeria deKayi, Storeria occipitomaculata, Thamnophis sauritus, Thamnophis sirtalis, Heterodon platyrhinos, Diadophis punctatus, Carphophis amoenus, Coluber constrictor, Opheodrys aestivus, Elaphe obsoleta, Lampropeltis calligaster, Lampropeltis getulus, Lampropeltis doliata.*

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Mammals of Vigo County, Indiana. JOHN O. WHITAKER, JR., Indiana State University.—A study of the mammals of Vigo County, Indiana was conducted from August 1962 to August 1965. A total of 2763 mammals were examined, including 1506 taken by means of snap-trapping in 430 of 500 randomly selected 25 x 25 meter plots, 812 taken in snap-traps set in lines in selected areas of the county, 230 mammals observed as roadkills, and 44 bats which were shot. The remainder were taken by other people.

Forty-one species of mammals were observed and are listed below together with the numbers examined of each. MARSUPIALIA: *Didelphis marsupiaiis* 26, INSECTIVORA: *Scalopus aquaticus* 18, *Sorex cinereus* 8, *Sorex longirostris* 2, *Cryptotis parva* 56, *Blarina brevicauda* 56, CHIROPTERA: *Myotis lucifugus* 6, *Myotis keenii* 4, *Myotis sodalis* 5, *Lasionycteris noctivagans* 1, *Pipistrellis subflavus* 17, *Eptesicus fuscus* 92, *Lasiurus borealis* 57, *Lasiurus cinereus* 3, *Nycticeius humeralis* 1, CARNIVORA: *Procyon lotor* 25, *Mustela nivalis* 2, *Mustela frenata* 1, *Mustela vison* 3, *Mephitis mephitis* 16, *Taxidea taxus* 2, *Vulpes fulva* 1, *Urocyon cinereoargenteus* 6, RODENTIA: *Marmota monax* 15, *Citellus tridecemlineatus* 74, *Tamias striatus* 13, *Sciurus niger* 37, *Glaucomys volans* 7, *Castor canadensis*, 1 seen, *Peromyscus maniculatus bairdii* 594, *Peromyscus leucopus* 364, *Synaptomys cooperi* 5, *Microtus pennsylvanicus* 120, *Microtus ochrogaster* 181, *Pitymys pinetorum* 18, *Ondatra zibethica* 53, *Rattus norvegicus* 14, *Mus musculus* 748, *Zapus hudsonius* 42, LAGOMORPHA: *Sylvilagus floridanus* 68, ARTIODACTYLA: *Odocoileus virginianus* 1.

The gray squirrel, *Sciurus carolinensis*, may also be present but no individuals have been seen.

Population Dynamics of a *Myotis lucifugus* Colony in Boone County, Indiana. STEPHEN R. HUMPHREY and JAMES B. COPE, Earlham College.—

Observations were made of a nursery colony of little brown bats (*Myotis lucifugus*) near Thorntown, Boone County, Indiana, from April until October in 1964 and 1965, and other colonies in Indiana were checked in relation to some problems. Investigation within a square mile showed that the entire population roosted in two adjacent buildings. Population fluctuations were followed by counting the bats as they flew out at dusk, and this technique was found to provide a more accurate count than estimating numbers while catching bats in the buildings. The population fluctuations that are discussed are reactions to human disturbance, arrival of bats during spring, the attaining of flight by young bats, and departure of bats in fall; variation in these fluctuations is noted in comparing 1964 and 1965. Observations on reproduction pertain to embryo development and birth data, and sex ratios of young and adults are described. A few interesting movements of bats from the colony are discussed.

A Comparison of Food Habits of Two Species of *Microtus*. EARL G. ZIMMERMAN, Indiana State University (Present address: University of Illinois).—A system of stratified random sampling was employed in the Terre Haute Quadrangle, Vigo County, Indiana, to obtain *Microtus ochrogaster* and *M. pennsylvanicus* for a food habits comparison. Epidermal structures of plants found in the field were compared with those found in stomachs to determine foods eaten. The important foods of *M. pennsylvanicus* were *Poa, Panicum,* and *Muhlenbergia* comprising 32.1%, 24.7%, and 14.6% of the volume, respectively. The more important foods for *M. ochrogaster* were *Poa*, roots, and *Trifolium* making up 15.8%, 10.0%, and 9.7% of the volume, respectively. *M. ochrogaster* stomachs contained a greater variety of foods than *M. pennsylvanicus,* probably due to the greater numbers of species of plants in the habitat. *M. ochrogaster* ate 4.7% insect material and .6% *Endogone,* and *M. pennsylvanicus* ate 3.6% insect material and 2.1% *Endogone.* In general the more abundant plants in the habitat were the most important foods. Certain plants, *Ambrosia, Aster,* and *Solidago,* were avoided.

Persistent Rhythms of Locomotion Activity in the Turtle, *Pseudemys scripta*. WILLIAM J. BRETT, Indiana State University.—The spontaneous activity of small turtles (1½-2 inches in diameter) under conditions of constant low illumination and relatively constant temperature was recorded for four periods of roughly 30 days each. The activity of six turtles was recorded for each of the four periods. During the last two periods additional groups of turtles were placed in a large fine mesh copper screen container and the spontaneous activity of six of these turtles was recorded. Analyses of the activity data revealed an average solar day cycle in both the controls and the experimentals with an increase in activity from midnight to 7 a.m. and then a sudden decrease in activity until noon remaining low until the rapid increase at midnight. A randomizing of the solar day cycle revealed a lunar day cycle in both groups but the phases of the cycle were almost completely reversed between the two groups. Using total daily activity for all animals, it was possible to demonstrate the presence of a lunar month cycle with a minimum at new moon and maxima closely related to the other three phases.

Development of Dusting Pattern in Young Quail ***Coturnix coturnix japonica.*** WILLIAM J. BRETT and MARILYN KRUSE, Indiana State University.—Groups of 8-12 quail were maintained from hatching until three weeks of age in plain wire bottom brooders. The quail were removed from the brooder each day and placed in a container with a substrate of ground corn cobs. The activities of the birds over a 15-minute period were observed and recorded. The activities were categorized as related to the normal adult dusting pattern. It was found that a definite chronological sequence of activities occur. Pecking occurs on the first day, scratching on the fourth or fifth day and complete dusting on about the ninth day.

Some Studies of the Succession of Saprophagous Arthropods on Carcasses of Animals. J. HILL HAMON and JAMES S. HASEMAN, Indiana State University.—Carcasses of turtles and chickens were placed in ground cages in xeric, mesic, and hydric ecological localities in Alachua County in north-central Florida, and in Vigo and Sullivan Counties in western Indiana. Saprophagous arthropods were observed and collected as they came to the carcasses. A basic succession in order of appearance of the various species of arthropods at the observation sites was apparent. The greatest variation in the different ecological habitats was in the number of arthropods, and the rate of decay of the carcasses. Some seasonal variations in this succession probably exists.

Some Preliminary Studies in the Succession of Bacteria Responsible for Maceration of Birds. BARBARA TROYER, Indiana State University.—Standard bacteriological methods were employed to isolate and identify the bacterial organisms responsible for the maceration of birds in water. Factors influencing the rate of decay include the type of water used, the age of specimens, container size, temperature, and frequency of "pouring-off." Members of *Aerobacter*, *Escherichia*, *Alcaligenes*, and *Clostridium* groups appeared to dominate. Preliminary studies indicate an aerobic and anaerobic bacterial succession does exist.

Some Problems in the Osteology of Passeriform Birds. J. HILL HAMON, Indiana State University.—The order Passeriformes includes over half of the birds of the world, yet no complete osteological study has ever been made for a single species. Some groups are presently undergoing explosive radiation, and many taxa created by the taxonomists are artificial. Some problems involved in the use of osteology as a taxonomic criterion are discussed.

Some Studies of the Ossification of the Skull of ***Coturnix coturnix japonica.*** MARILYN F. CAMPBELL, Indiana State University and Danville Junior College, Danville, Illinois.—The skulls of one hundred Japanese quail (*Coturnix c. japonica*) of known ages were cleared and stained and examined under a binocular microscope. Sixteen skulls of selected ages were photographed and subjected to radiological examination.

At the time of hatching, definite centers of ossification are found in the occipital region of the cranium, the nasals, and the hyoid apparatus. Ossification follows a definite pattern, moving anteriorly and laterally from the occipital region at a rapid rate.

All of the non-kinetic bones of the skull except the maxillaries, jugals, and quadratojugals, and some in the hyoid are fused by the twenty-fourth day. A period of increased skull density and development of the hyoid occurs from thirty to forty days of age. At the end of this period, the maxillaries, jugals, and quadratojugals are fused. At sixty days the hyoid apparatus is complete and the cranium begins to take on the characteristics of the adult skull. At this time the quail is reproductively mature.

The degree of ossification and measurements of the skull can be used to determine the age of hatchlings up to three weeks in age. The development of the hyoid apparatus appears to be the best indicator of age in the Japanese quail between the ages of twenty-four and sixty days.

The Number of Contour Feathers in Some of the Falconiformes. J. HILL HAMON and WILLIAM W. MORGAN, Indiana State University.—There has been only one feather count made for a falconid bird, that of an immature bald eagle. Because of lack of information about this neglected area of basic avian anatomy feather counts are being made at Indiana State University. Four species have been counted to date, *Accipiter striatus, Falco sparverius, Buteo jamaicensis,* and *Cathartes aura.* Individual pterylae were counted, and observations were made on the characteristics of the contour feathers.

Weight Reversal in Heat-Stressed Chick Embryos. W. C. GUNTHER, Valparaiso University.—Previous reports by Gunther and Jones in 1961 indicated that chicks hatched from eggs incubated initially for 3 days at the nonoptimally high temperature of 41° C. weighed significantly less at hatching than did the controls. However, during the initial phases of incubation at least, it had been ascertained that heat-stressed embryos weighed nearly twice as much as the controls. In an effort to learn when during the incubation period experimental chicks began to lose weight, a total of 428 presumably healthy, living embryos were removed from eggs. They were trimmed of all membranes and were wet-weighed, after which they were killed and fixed. Statistical tests indicated that the experimental embryos began to lose weight relative to that of the controls from the 6th day of incubation, and that by the 10th day of incubation there was no significant difference in their weights. Embryos were not weighed beyond the 10th day of incubation.

Beta-alanine utilization in *Drosophila* with notes on other amimo acids. M. E. JACOBS, Goshen College, Goshen, Indiana.—Injection of early pupae and adults of *Drosophila melanogaster* with C-14 labeled beta-alanine disclosed that non-ebony deposited much more beta-alanine in the integument than did ebony and excreted $C^{14}O_2$ at a diminished rate, while heterozygotes were intermediate in these activities. Gamma-aminobutyric and aspartic acids behaved somewhat similarly but to a much lesser degree. The effect was not observed with glycine, leucine, valine, or phenylalanine.

The Effect of Diet on Fatty Acid Profiles in the Cockroach, *Blaberus discoidalis*. JOHN L. MCGUIRE[1] and ARNOLD E. S. GUSSIN, Butler University.—Some investigators have suggested that the lipid composition of an insect's tissues may be influenced by the lipid components of the diet; indeed, some have ascribed all unusual fatty acid profiles encountered in the insect to dietary influences. Other workers have found that the insect can biosynthesize tissue fatty acids from other dietary fatty acids and/or from dietary carbohydrate. In order to determine whether or not diet influenced the fat body fatty acid composition of the cockroach, the insects were maintained on two experimental diets. One diet contained 22 percent of short chain fatty acids and about 8 percent of an unknown longer chain fatty acid (Diet I); the other consisted of about 4 percent of the short chain acids and none of the unidentified acid (Diet II). Both were essentially identical with regard to other fatty acids.

Fatty acids were extracted from the insect's fat bodies and assayed by gas-liquid chromatography. Insects fed Diet I contained about 5 percent of the unknown fatty acid. There was a marked decrease in the percentage of short chain fatty acids in the fat body relative to that of the diet. Other fatty acids maintained their same relative percentage in the fat body. The insects maintained on Diet II did not exhibit a marked variation in the percentage of short chain fatty acids and did not biosynthesize the unknown longer chain fatty acid. Thus, the fatty acid profile of *Blaberus discoidalis* is probably influenced by both diet and biosynthetic interconversions.

Uptake and Retention of Zirconium-95, Niobium-95 in the Sea Squirt (*Molgula manhattensis* De Kay). RAYMOND E. HENZLIK, Ball State University.—It is well established that a variety of bottom-dwelling organisms living in estuarine environments can accumulate and concentrate radioisotopes. Some of these organisms are of direct economic importance to mankind; others are of ecological interest as steps in food-chains, as evidence of nuclear activities by man, and as biological indicators of the presence and degree of radioactive contamination. This particular investigation deals with the common benthic animal, *Molgula manhattensis* (a simple ascidian) that is abundant in the estuarine ecosystems around Beaufort, North Carolina. The accumulation and retention of the radionuclides zirconium-95 and niobium-95 were followed, and comparisons were made with other sessile benthic invertebrates whose role in the cycling of certain radionuclides had been previously elucidated. Localization of the radioactivity in the tissues and organs of the tunicate was also investigated.

The facilities of the Radiobiological Laboratory of the Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service, Beaufort, North Carolina, were made available for this study in conjunction with an NSF summer research grant to North Carolina State University.

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Absence of Hyperglycemic Response at or After Ecdysis in ***Xiphosura polyphemus.*** HENRY TAMAR.—Groups of 6 small Limulii (carapace width 6.2-8.2 cm.) were selected either for a hard exoskeleton or a soft one with resilient carapace. A 0.5cc. pre-injection blood sample was drawn from the pericardial sinus of each specimen, and then 0.5cc. of filtered sea water was injected at the same site. After 3 hours (at 26.5°-30°C) a post-injection pericardial sinus blood sample over 1.5cc. was drawn. Blood glucose level was determined with the enzymatic Glucostat reagent and a Beckman DU spectrophotometer.

The average pre-injection blood glucose level for 30 Limulii with a hard exoskeleton was 4.0 mg./100 ml., s.d. 2.1. The post-injection average for 24 of these hard-skeletoned animals was 20.1 mg. glucose/100 ml., s.d. 10.4. Their average increase in blood glucose was 15.9 mg./100 ml. The pre-injection average of 24 soft-skeletoned specimens was 2.6 mg. glucose/100 ml., s.d. 1.4, and their post-injection average was 1.0 mg./100 ml., s.d. 0.8. This represents an average drop of 1.6 mg. glucose/100 ml. of fluid. The differences between the means for post-injection hard and post-injection soft, pre-injection hard and post-injection hard, and pre-injection soft and post-injection soft animals were significant beyond the .001 level. Apparently the appearance of hyperglycemic response in Xiphosura can be dependent on the stage of the molting cycle.
Supported by PHS Grant 5TI GM 1030-03. (Indiana State University)

The Effects of Amino-glutethimide on the Rat Ovary. D. J. THOMPSON and W. J. EVERSOLE, Indiana State University, Terre Haute, Indiana. —Amino-glutethimide, a central nervous system depressant and anticonvulsant, was injected subcutaneously daily in a dose of 25 mg/Kg or 50 mg/Kg for two weeks into Charles River CD strain immature female rats. One set of rats was 21 days and another 28 days of age at initiation of the injections. Control rats were injected with either physiological saline or water. At autopsy the ovaries were dissected free of fallopian tube and extraneous fat, weighed on a torsion balance, and fixed for histological study. During the two-week treatment period the animals exhibited normal body weight gain and appeared to tolerate the drug without showing obvious symptoms of decline in general activity. The ovaries of the "21 day-old" treated groups were heavier than their controls, whereas the ovaries of the "28 day-old" treated groups were approximately the same weight as their controls. Histological studies of the gonads in the latter groups of treated rats showed an increase in number of vesicular follicles and a decline in number of corpora lutea. Studies are in progress on the histological structure of the ovaries from the "21 day-old" groups, and further plans are being made to extend these studies to various age groups and different dosage levels.

A New Troglobitic Isopod (Asellidae) from Southern Indiana

WILLIAM R. EBERLY, Manchester College

Blind, white isopods are common in most of the caves of southern Indiana. For the most part, specimens are easily referable to *Asellus* (=*Caecidotea*) *stygia* (Packard) Steeves (2). During the construction of Jordan Hall, the biology building at Indiana University in Bloomington, a subterranean stream was exposed by the excavation into the surface limestone strata. After the opening of the building in 1955, the stream continued to seep into an unfinished sub-basement room where it formed numerous small pools. Aggregating in these pools at times were large numbers of a very large isopod which subsequently was determined to belong to a new species. It is a pleasure to name this species in honor of David Starr Jordan, famous ichthyologist and early biology teacher at Indiana University, for whom Jordan Hall is also named.

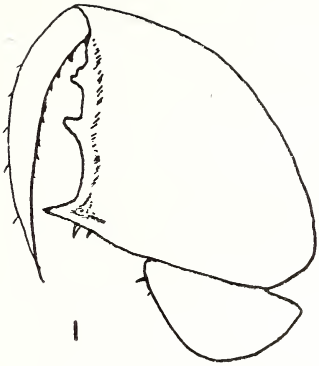
Asellus jordani, nov. spec.

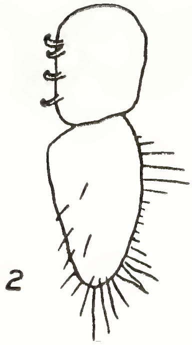
Diagnosis. Albinistic, without eyes. Maximum body length 23 mm. in males, 15 mm. in females. Basal process of palmar margin of male propodus (fig. 1) large and triangular, median process large and not so pointed, located close to distal process, which is bidentate and crowded close to joint with dactyl; propodus of female similar but narrower and less inflated. First pleopod (fig. 2) with four coupling hooks on inner margin of the basal segment; lateral setae on distal segment in two series, longest at tip and near proximal end. Second pleopod of male (fig. 3) with elongate basal segment about 3/5 the total length of appendage; distal joint of expodite fringed with long plumose setae, longest at tip; endopodite with prominent mesial apophysis near base and terminating in three distinct parts (fig. 4): (1) a laterally directed, acutely pointed canula (can), (2) a finger-like caudal process (ca), (3) a much reduced lateral process (la) lying above the caudal process and not extending beyond the slightly crenulate distolateral margin of the endopodite. Uropod up to 1.25 times as long as pleotelson; endopodite about 0.6 times as long as peduncle; exopodite about 0.4 times as long as endopodite.

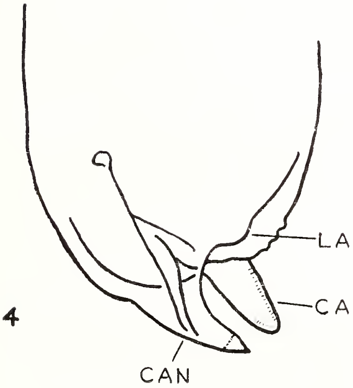
Type locality. Seep in sub-basement of Jordan Hall, Indiana University, Bloomington, Indiana.

Remarks. This species is probably the largest troglobitic asellid known from the United States. It very clearly belongs to the Stygius group of Steeves (2). It can be distinguished from *A. stygius*, the only other albinistic asellid so far known from Indiana, by the massive triangular basal process of the propodus, which is represented by a large spine in *stygius*, the straight instead of recurved tip of the canula, four coupling hooks instead of five on the basal segment of the first pleopod, rounded instead of broadly truncate tip of the distal segment of the first pleopod, etc.

Body proportions, of course, change with age as in all asellids (1). Immature specimens are very compact with the thoracic segments being







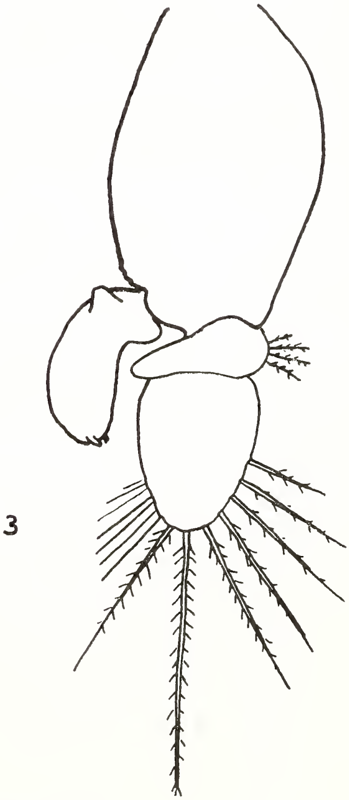


Figure 1. Gnathopod of male.
Figure 2. Cephalic view of first pleopod, male.
Figure 3. Cephalic view of second pleopod, male.
Figure 4. Detail of cephalic aspect of tip of endopodite of male second pleopod. LA—lateral process. CA—caudal process. CAN—canula.

wider than long. In large mature specimens, the dorsal thoracic tergal plates are usually longer than wide and are distinctly separated from each other.

A series of 52 specimens was collected by Mr. John de Costa in March, 1960, and an additional 14 specimens were collected by the writer in February, 1961. The holotype (male), allotype and 15 paratypes are deposited in the United States National Museum, 12 paratypes with Dr. Harrison R. Steeves, III, Department of Anatomy, University of Alabama Medical Center, Birmingham, Alabama, and the remaining paratypes in the collection of the author.

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The Introduction of the Japanese Quail (*Coturnix coturnix japonica*) in Indiana

RALPH D. KIRKPATRICK, Indiana University Southeastern Campus[1]

The Japanese Quail (*Coturnix coturnix japonica*) was introduced into Indiana during the period 1956 through 1959. The Indiana Department of Conservation initiated the propagation and release of this exotic game bird after interest was aroused by the Missouri Department of Conservation. It was hoped that this bird would utilize habitat not suitable for native species.

The Missouri Department of Conservation arranged for interested states and individuals to purchase breeding stock produced by their study birds on a privately owned Missouri game farm. A cooperative study of the Japanese Quail was begun with the mutual agreement of 12 states to exchange reports concerning the progress of their investigations. Cooperating states were Florida, Illinois, Indiana, Kentucky, Missouri, Nebraska, New Hampshire, North Carolina, Ohio, Oklahoma, Tennessee and Texas.

The Indiana Department of Conservation purchased 50 pairs of Japanese Quail from the game farm in Missouri in April 1956. A total of $600.00 was paid for the breeding stock. Breeders were held at the Muscatatuck State Game Farm near North Vernon, Indiana. Bobwhite Quail (*Colinus virginianus*) were being raised at this facility at the same time, and the same equipment and feed were used for both species. Propagation methods differed for the two species in certain respects,

TABLE 1

Spring and summer releases of Japanese Quail made by the Indiana Department of Conservation.

Release County	Year of Release	Total Released
Grant	1957	4,084
	1958	1,999
Montgomery	1957	4,063
	1958	1,000
Newton	1957	1,949
	1958	999
Kosciusko	1956	253
	1957	3,549
	1958	1,000
Total		18,896

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[1] Data were collected while author was a Game Research Biologist, Indiana Department of Conservation. The author gratefully acknowledges the assistance of Dr. Russell E. Mumford, Purdue University, and the following Indiana Department of Conservation biologists: Clayton Bushong, Wm. E. Madden, James D. McCall, Tom Weddle, and John M. Allen.

however. All released birds were individually marked by means of numbered metal leg bands.

Spring and summer releases of Japanese Quail (Table 1) were made. Release sites were selected in four of Barnes' (1) zoogeographic regions in northern and central Indiana. Releases in the Central Tipton Till Plain Zoogeographic Region were made three miles northeast of Fairmount in Grant County. The Prairie Fringe Zoogeographic Region releases were made five miles north of Darlington in Montgomery County. Releases were made on the Willow Slough State Fish and Game Area in Newton County in the Kankakee Sands Zoogeographic Region. Tri-County State Fish and Game Area in Kosciusko County was used for releases in the Northeastern Lake Zoogeographic Region.

Japanese Quail were released on public hunting areas for controlled shooting purposes (Table 2) during the hunting seasons of 1956, 1957, and 1958. Liberations were made on the Crosley State Fish and Game Area in the Southeastern Lowland and Flats Zoogeographic Region, and on the Willow Slough and Tri-County State Fish and Game Areas.

TABLE 2

Japanese Quail released by the Indiana Department of Conservation for controlled shooting.

Release Site	Year of Release	Total Released
Crosley State Fish and Game Area	1958	400
Willow Slough State Fish and Game Area	1957	3,980
	1958	1,143
Tri-County State Fish and Game Area	1956	329
	1957	2,612
	1958	700
Total		9,164

Indiana sportsmen released at least 1,288 Japanese Quail in 14 counties during the period of 1956 through 1959 (Table 3). Birds for these releases were purchased from private game farms or, in some instances, were obtained from the Muscatatuck State Game Farm. An undetermined number of birds was released in various counties without being reported. The Indiana Department of Conservation did not officially provide birds for sportsmen to liberate.

Quail released during the spring and summer (Table 1) disappeared from the study areas within weeks or months after liberation. Birds released in 1956 were not found on the study area after the first week of December of that year. None are known to have returned in 1957.

Quail released in 1957 had disappeared from the Grant County study area by the second week in November, from the Montgomery County study area by the middle of December, from Willow Slough by December 1, and from Tri-County by the end of November. A Grant County farmer observed two Japanese Quail during the first week of April 1958 prior to that year's releases. Birds also returned to Montgomery County

TABLE 3

Japanese Quail released by Indiana sportsmen.

County of Release	Year of Release	Total Released
Fayette	1956	30
La Grange	1956	100
Steuben	1956	100
Decatur	1957	32
Dubois	1957	20
Elkhart	1957	250
Franklin	1957	8
Johnson	1957	8
Porter	1957	37
Elkhart	1958	200
Hamilton	1958	50
Kosciusko	1958	78
Porter	1958	37
Clark	1959	50
Daviess	1959	288
Total		1,288

early in 1958. A farmer observed an adult on April 10. Clayton Bushong collected an unbanded, adult male and observed another adult on April 11. Farmers observed three additional birds on the study area during April. A pair of adults was observed on June 15.

Conservation department biologists on Willow Slough heard and observed Japanese Quail many times from early spring to August 8, 1958.

A biologist at Tri-County flushed five to seven Japanese Quail on April 16, 1958.

Birds released in 1958 disappeared from Grant County by the last week in December, from Montgomery County by December 16, from Willow Slough by December 3, and from Tri-County by October 20.

A male was heard calling in Grant County on June 20, 1959. Two birds were observed in Montgomery County during the spring of 1959. These constitute the last reports of wild Japanese Quail in Indiana.

The return of birds to release sites during the spring following their liberation in the preceding year has not previously been reported (3).

Mortality among released birds occurred as the result of inclement weather, accidents (as getting in the way of moving farm equipment and flying into trees and woven-wire fences), and predation. Known predators include domestic cats (*Felis catus*), dogs (*Canis familiaris*), red foxes (*Vulpes fulva*), Crows (*Corvus brachyrhyrchos*), Sparrow Hawks (*Falco sparverius*), Cooper's Hawks (*Accipiter cooperii*), and Red-tailed Hawks (*Buteo jamaicensis*).

A limited amount of reproduction occurred on the study areas during each year of this investigation. Young birds were observed in grain and hay fields and in pastures.

Although 18,896 birds were liberated during the spring and summer (Table 2), a total of but 27 were recovered more than ten miles from the points of release (2). The recoveries indicated that the birds had moved in various directions, but usually had moved in a southerly direction from the release sites. Only two of the recovered birds had been in the wild as long as six months. Birds were recovered in the states of Indiana (9 birds), Kentucky (6 birds), Mississippi (3 birds), Tennessee (2 birds), Virginia (2 birds), Alabama (2 birds), Ohio (1 bird), Maryland (1 bird), and Georgia (1 bird).

Collected data indicate that quail released for controlled shooting exhibited even poorer survival than the birds released during the spring and summer. Within days following release, birds had disappeared, even though hunters killed only 34.9 to 60.5 per cent of the total birds released (Table 2). Birds released during hunting seasons were not recovered, at any time, outside the public hunting areas.

The Japanese Quail is not established in Indiana. Due to the apparent lack of success of the introduction, I recommended that the Indiana Department of Conservation cease the propagation of this game bird. I also recommended that its release by sportsmen should be discouraged, for economic reasons.

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Two Elephantine Teeth from the Mill Creek Drainage Area

ALBERT E. REYNOLDS, DePauw University

In a previous report (Reynolds, 3) a description was given of a mastodont tooth which was plowed up near Mud Creek in Hendricks County. The report elicited a certain measure of local interest which has resulted in attention being called to two additional teeth, both discovered some time ago, but from the same general Mill Creek drainage area. Both of these teeth were made available through the courtesy of Mr. Chauncey Phillips of Coatesville, Indiana, and the present report is for the purpose of making them a matter of record.

It was at once apparent that these two teeth were not mastodont, but of elephantine origin, since they exhibited diagnostically characteristic "ridge-plates." In the teeth of the elephant or mammoth, the crown is characterized by an antero-posterior succession of these ridge-plates, each of which is thin and compressed antero-posteriorly. Their lateral or transverse dimensions approximately determine tooth width, and in the vertical dimension the upgrowth of the ridge plates from the root largely determines crown height. Each ridge plate is a wafer-like sheet of dentine clothed on all surfaces (except basally) by a thin sheet of enamel. The ridge plates do not abut against each other directly, but are both separated and bound together by a layer of cement which also encases the outer surfaces of the tooth. In growth pattern, ridge plates appeared in antero-posterior succession in time. As the organism used the teeth in chewing the abrasive material of the diet, the upper surfaces of the teeth became worn, and such wear would be evident on anterior ridge plates before some of the posterior ones had put in appearance. As soon as the enamel coat on the tops of the ridge plates wore through, the worn portion of a tooth would present a characteristic corrugated appearance, wherein the corrugations consisted of alternate high and low bands extending transversely across the tooth chewing surface. The higher bands were ridges due to the harder enamel, while the lower bands were due to the softer dentine or cement; the sequence of these transverse corrugations would be: enamel-dentine-enamel-cement-enamel-dentine-enamel-, etc. The permanent teeth of the mammoth consisted of three molars in each quadrant of the jaws, and these, too, appeared in antero-posterior sequence. A preceding molar would be so worn down by the time its successor was full-grown that the latter would boost the former out of the jaw. This brief account has been based on the more detailed treatment given by Hay(1) and Osborn(2).

The two teeth which form the subjects of this report were of considerably different sizes and weights.

Large Tooth

This tooth, weighing 1.53 Kg (3 lbs. 6 oz.) in its present condition, was in only a fair state of preservation. Truncations at each end, and the crumbled nature of its grinding surface, both attest to loss of parts and resulting incompleteness (Fig. 1). The root of the tooth extended

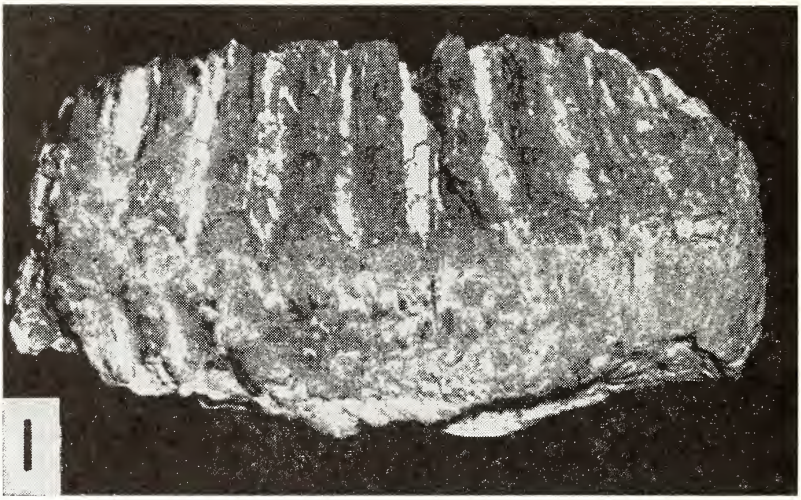

Figure 1. Large tooth in side view with crown uppermost, root below. From root-crown junction the sides of seven ridge plates are visible as darker columns between lighter layers of cement. Photograph, X 0.6 approximately.

downward only 45 mm from the root-crown junction, and the root was 180 mm in antero-posterior greatest length. From its top or grinding-surface aspect (Fig. 2), the tooth exhibited a straighter side 170 mm long and a more curved side 150 mm in antero-posterior length, both measured at mid-crown height. Crown height was determined by averaging the heights of the separate ridge plates; this mean height was 54.5 mm on the curved (convex) side, 53.6 mm on the straighter side.

As to the number of ridge plates on this tooth, evidence existed for ten such plates, eight of which were clear and well-defined (Fig. 1). These ranged from 7.7 to 11.2 mm in antero-posterior thickness, averaging 8.8 mm. The dentine cores of these plates varied from 3.7 to 6.3 mm in thickness, with a mean of 4.7 mm, while the covering coats of enamel were 2.2 mm in mean thickness. Intervening between the ridge plates were the layers of cement (Fig. 2) which averaged 7.6 mm in thickness, varying from 2.3 mm to 8.8 mm.

Tooth width may be adjudged by the transverse measurements of the ridge plates, measurements which varied from 73 mm to 90 mm, averaging 86 mm. This does not reflect the true original tooth width, however, for mammoth teeth characteristically had an outer coating or encasement of cement (1, 2). In the some 15,000 years since the Pleistocene or post-Pleistocene demise of this tooth's owner, this outer encasement of cement has leached, dissolved, or crumbled away. This has rendered clearly visible the sides of the ridge plates as rounded edges, and also made clearly evident the root-crown junction (Fig. 1).

On the basis of the location from which this tooth was taken, it is reasonable to assume that it came from a specimen of *Parelephas jeffersonii*, which had a widespread occurrence throughout the middle United States (2). A descriptive statistic utilized by both Osborn (2)

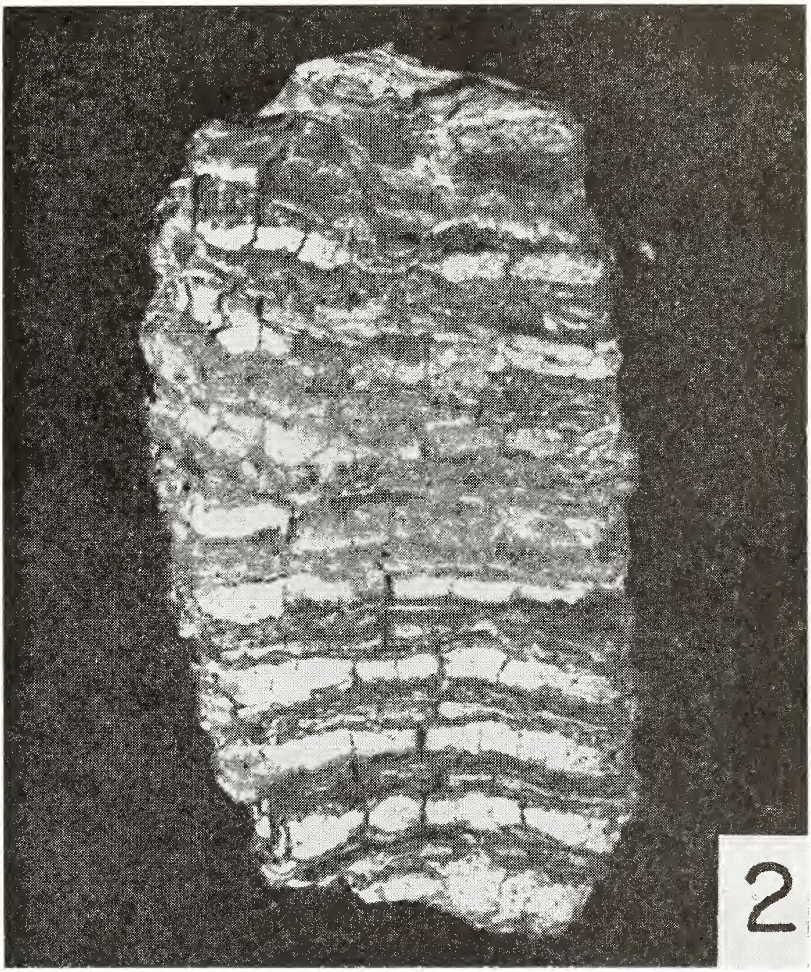

Figure 2. Large tooth, view of grinding surface. Note lighter transverse bands of cement alternating with ridge plates. Ridge plates exhibit thin light streaks of dentine sandwiched between darker enamel sheets. Photograph, X 0.65 approximately.

and Hay (1) for mammoth teeth was the number of ridge plates occurring within 100 mm of linear length. When applied to this tooth, there were 7 ridge plates in 100 mm on the grinding surface. On the straighter side of the tooth, 100 mm encompassed 6½ plates near the summit, 6 plates at mid-crown height, and 5½ plates at the base of the crown. These values indicate a tendency toward increased compression of the ridge plates as they grow upward, a relationship noted by Osborn (2).

The incompleteness of this tooth practically obviates any accurate identification with reference to exact jaw and jaw position. With a width of approximately 86 mm, it could conceivably be either a second or third molar, both of which fall within the range of 60 to 90 mm in reported width (1, 2). Reported lengths for third molars have been 228 to 355 mm, for second molars 165 to 300 mm, and these measurements might render reasonable the classification of this tooth as a second molar since its length in its present state places it in the 150 to 180 mm range. Any attempt to allocate the tooth further to right or left side or to upper or lower jaw would be largely speculative because of insufficient evidence.

Small Tooth

This smaller tooth, weighing 0.5 Kg, was relatively more complete than the larger one described above. The grinding surface was ovoid in shape, and had a transverse dimension (greatest width) of 68.2 mm. Viewed from the side, the tooth was approximately triangular in shape due to the taper from grinding surface to tip of the root (Fig. 3). The greatest antero-posterior dimension occurred at the grinding surface which had a length of 112.6 mm. On one end of the grinding surface, interpreted here as the anterior end, there occurred a plate 40 mm in

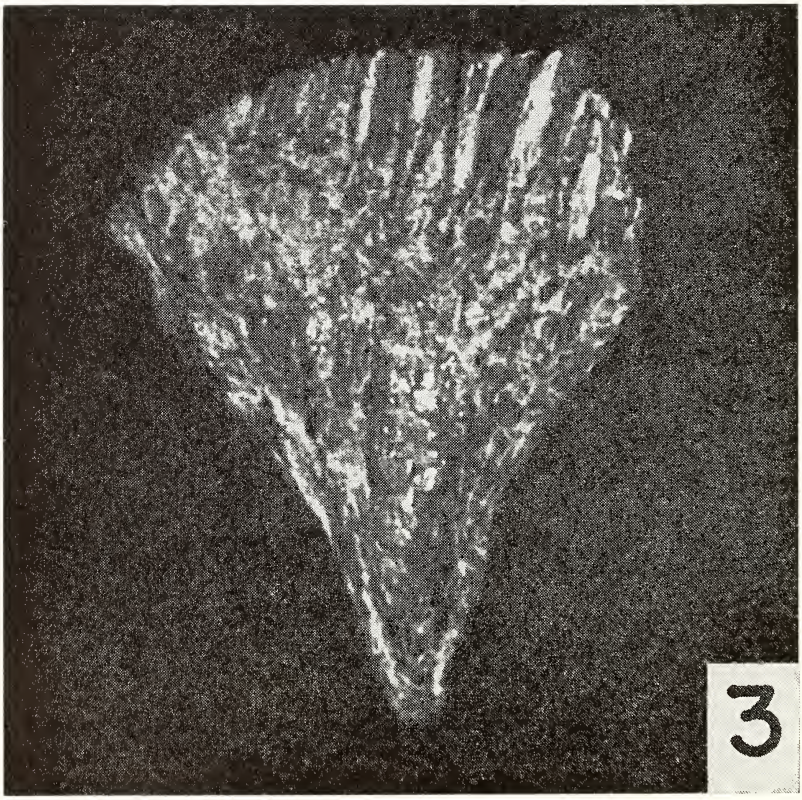

Figure 3. Small tooth in side view. Note progressive decrease in height of ridge plates from right to left. Photograph, X 0.65 approximately.

length which exhibited no ridge plates; this has been interpreted as being due to wear, since faint indications of ridge plate bases could be detected on one side of the tooth in a position underlying this plate. In height, the shortest ridge plate occurred next to this ridge-free plate. The seven quite visible ridge plates of the tooth were of progressively greater heights (Fig. 3), the highest being 42.0 mm, and occurring at what is presumed to be the posterior end of the crown. Some breakage at this end of the crown had not obliterated evidence for two more ridge plates. From crown to tip of the root, over-all height of the tooth was 126.0 mm. The mean antero-posterior thickness for the seven well-defined ridge plates was 6.0 mm, with dentine cores averaging 2.2 mm in thickness and the covering coats of enamel had a mean thickness of 1.86 mm. The cement layers between ridge plates averaged 4.03 mm in thickness.

It was assumed that this tooth also came from a specimen of *Parelephas jeffersonii,* which is the same animal described by Hay (1) as the "Hairy Mammoth," *Elephas primigenius* (2). On the basis of its general size and a few other characteristics, it is probably a third milk molar, based on criteria given by Hay (1). Since its grinding surface is convex from front to back, it most likely came from the upper jaw.

Discussion

The two teeth just described are not of recent discovery; both have been in the possession of the finders for approximately two decades. Personal visits to the discovery sites with the finders of the teeth were not feasible, but the teeth were accompanied by collection-site information. The larger tooth was discovered north of Stilesville, Indiana, by Mr. Clarence Stubblefield, at a spot near a fork of Mill Creek. Such a fork occurs somewhat less than 1.5 miles north of Stilesville where Crittenden Creek flows into Mill Creek. This stream junction lies approximately at latitude 39°39′14″ north, longitude 86°37′48″ west, and occurs in Section 15, Township 14 North, Range 2 West, in Hendricks County, Indiana. The smaller tooth was discovered by Mr. Daniel Stone "a mile south and a mile east of Stilesville." This description would place the site at approximately latitude 39°37′20″ north, longitude 86°36′49″ west, which would be in Section 27, Township 14 North, Range 2 West; the site would occur very near the east edge of the section, and about mid-section in the north-south direction.

From the large tooth discovery site near the Crittenden-Mill Creek junction, the small tooth discovery site is about 2.3 miles distant in a straight line (5, 6), and lies south-southeast (actual azimuth 157°) from it. A Mastodon tooth described earlier (3) was found at a site which occurred 0.5 mile south and 2.5 miles east of the small tooth discovery site. Both mammoth tooth discovery sites bear an interesting relation to a glacial lake, Lake Eminence, which was formed back (north) of the Early Wisconsin (Shelbyville) moraine, according to Thornbury (4). Lake Eminence extended north into the present Hendricks County in two finger-like extensions, one of which projected almost to the present site of Stilesville. The smaller tooth came from a location very close to the eastern boundary of this extension of the lake, while the larger tooth came from a spot about 1.5 miles north of the northern Lake Eminence boundary.

Summary

Two teeth discovered approximately two decades ago in Hendricks County, Indiana, were identified as elephantine on the basis of their ridge-plate structure, and allocated to *Parelephas jeffersonii* on the basis of the discovery sites near Stilesville. Both teeth were described in quantified terms, and the approximate sites of discovery discussed briefly in relation to their proximity to Lake Eminence of the late Wisconsin glacial epoch.

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Recent Indiana Fish Collections With Notes on Five New or Rare Species

H. E. McReynolds, Department of Natural Resources

Temporal changes in a state's ichthyofauna are to be expected in view of natural selection and Man's own interference with Nature. The discovery of new or rare forms within a geographical entity generally shows a correlation with the intensity of collecting. It would seem logical that the greater the number of collectors and collections of fish, the greater the probability of new forms being uncovered. In fact, this premise is so fundamentally simple that we tend to forget that it is true only if certain basic considerations are met.

The first requirement is of such an elementary nature that we often overlook it—simply that a new species must be collected by a person capable of recognizing it as such, and with an inclination to report the capture. It is quite probable that members of unreported species have been impaled on fishermens' hooks. More than one state prototype may have lured old *Micropterus* to his doom and *Latimeria* itself seemed to have been no atavistic specter to native African fishermen. Further, should a new form fall into the hands of that rare fisherman who is as conversant with dichotomous keys as with "Sports Afield," it is still rather unlikely that he will record it for the avid eyes of posterity's taxonomists.

The second qualification concerns the coverage or distribution of the collections. Considering like numbers of collections, the discovery of new forms is generally more probable if collections, though of lower spatial density, are spread throughout most of the drainage of the state. Shoemaker (8) collected fish from 41 sites in Wayne County, Indiana. Gerking (2) in his state-wide distributional study, collected at 412 sites. Shoemaker (8) found 57 species in his 41 collections. However, Gerking's first 41 sites, chiefly in north-central Indiana, yielded 72 species. McReynolds (7) collecting in the Muscatatuck River drainage, records 68 species from 96 sites; Gerking lists 45 species after collections at 12 sites in this drainage. Yet Gerking's first 96 widely-scattered sites produced 91 species.

During his tenure at Indiana University in the late 1800's, David Starr Jordan, along with his colleagues and his students, made an appreciable number of collections in Indiana. However, between 1900 and 1955 there were only two significant contributions to the state's ichthyologia. These were the aforementioned series of 41 collections by Hurst Shoemaker in Wayne County (1942), and 412 collections by Shelby Gerking (1940-1943) in his distributional study. Since 1955 there has been a mild renaissance of the Jordanian period of scientific collecting.

With the initiation of the Ohio River Sanitation Commission studies, in 1957, Dr. Louis Krumholz (5), University of Louisville, began a fish faunal sampling program as a portion of the Ohio River Sanitation Commission studies. While many of his collections were made in the

Ohio River itself, still other samples were taken in the lower portions of tributary streams. Though a variety of collecting gear was used in the main stream, rotenone was generally used in taking tributary samples. The author and his crew assisted Dr. Krumholz on three of the Indiana streams—Laughery, Tanners, and Indian-Kentuck creeks.

In the Laughery Creek collection (No. 25, August 13, 1957), the first authenticated Indiana specimen of the shorthead redhorse (*Moxostoma breviceps*) was captured. This specimen weighed 0.14 pounds. Two days later (August 15, 1957) three other individuals of this species were taken in Collection No. 29 from the Big Blue River near Leavenworth. The combined Blue River specimens weighed .08 pounds. Jordan (4) lists *M. breviceps* in a collection from the West Fork of the White River at Spencer, Indiana. However, Jordan himself admits to much doubt concerning the validity of this identification. After listing the specimen(s) as *Moxostoma breviceps*, Jordan comments: "This is the species called *Moxostoma crassilabre* by Jordan, Man. Vert., ed. 5. It is probably not *M. crassilabre* (Cope). It may be *M. conus* (Cope), and is probably Cope's *M. breviceps*, though the latter may really be *Placopharynx carinatus* (*Moxostoma carinatum*). This species is found in the great lakes in abundance, and it is not improbable that it is *Moxostoma leseuri* (Richardson)." Amidst all this confusion, it seems most likely that Jordan's specimen(s) are either *carinatum* or *aureolum* (= *macrolepidotum*).

In Gerking's survey he took some specimens of *aureolum* from Big Walnut Creek about 5 miles southwest of Greencastle, Indiana. Dr. James Gammon (1) of De Pauw University has recently collected moxostomids from the same area in the Big Walnut Creek basin from which Gerking reported *aureolum*. Gammon's specimens seem to fall inconclusively between *breviceps* and *aureolum*. Should further studies of Gammon's and Gerking's specimens establish them as actually *breviceps*, Gerking's specimens would chronologically pre-empt the present consideration of the Laughery Creek specimen as the first Indiana occurrence of *breviceps*.

On August 16, 1957, in the Little Blue River (ORSANCO Collection No. 30), Krumholz captured another species which had not previously been reported from Indiana. This was the threadfin shad (*Dorosoma petenense* [=*Signalosa petenensis*]) and but one specimen, weighing 0.03 pounds, was taken. While the presence of the threadfin shad in Indiana waters is based on a single specimen, there is little doubt that collecting in Ohio River tributaries would turn up other individuals of *S. petenense* Krumholz found this fish in Ohio River collections at least as far upstream as the Louisville area. In addition, ORSANCO Collection No. 68 was made by rotenoning Ohio River Navigation Lock No. 44, adjacent to the Indiana shore at Leavenworth, Indiana. In this collection alone 1,962 threadfin shad were captured. The threadfin shad is a southern species, quite common in the lower reaches of the Ohio River, which apparently is expanding its range upstream in this system. Intensive collecting in the lower Wabash River should substantiate its presence there, also.

Although not new state records, the capture of two other species in an Indiana ORSANCO collection is noteworthy. At Indian-Kentuck Creek

(ORSANCO Collection No. 32) the river redhorse (*Moxostoma carinatum*) was reported for the first time since 1909. Its last reported Indiana occurrence was near Mitchell (Hahn, 1909). Perhaps even more surprising than its reappearance, was the number of specimens of *carinatum* captured in Indian-Kentuck Creek. Krumholz lists 27 specimens with a combined weight of 13.41 pounds for this collection! This might lead one to suspect that in large streams rarity of collections rather than the paucity of the species is responsible for our failure to encounter the largewater inhabitants more often. Though I feel that this is generally true, there is little support for such a supposition in this particular instance, since Krumholz found only 13 other specimens of *carinatum* at only 3 other sites in the entire Ohio basin.

In the same Indian-Kentuck Creek collection, the occurrence of two specimens of the silverstripe shiner (*Notropis illecebrosus*) is recorded. This minnow was first reported in Indiana by Dr. Karl Lagler (6) from the Wabash River in Posey County. It was not captured by Gerking and this appears to be the second occurrence in Indiana waters.

The Indiana Division of Fish and Game grants collectors' permits to those individuals who intend to capture fish in the pursuit of scientific studies. For the past several years Dr. Phillip Smith (9) of the Illinois Natural History Survey has made collections in a number of Indiana streams. In his very thorough 1964 annual report to the Division, I noted that he listed the capture of a species not previously taken in Indiana waters. In his Little Pigeon Creek, Warrick County collection of October 30, 1964, Dr. Smith records three specimens of the ribbon shiner (*Notropis fumeus*). Although this shiner occurs in Illinois and western Kentucky, within my knowledge no one has previously reported its existence in Indiana. Dr. Smith submitted the specimens to me for examination and they appeared to be *fumeus*. For a definite identification of these notropids, they were sent to Dr. Reeve Bailey, Curator of Fishes, University of Michigan Museum of Zoology. Dr. Bailey gave a positive identification as *Notropis fumeus*, thus establishing this as a new species on the state list.

Gerking (3) lists 172 species as occurring in Indiana and adds to these 11 subspecies for a total of 183 reported forms. Bailey (personal communication) questions the validity of several of these trinomials until more exhaustive studies are made. This present paper lists three new forms (*Moxostoma breviceps*, *Dorosoma petenense*, and *Notropis fumeus*, bringing the state species total to 175.

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Localized Production of the Hatching Substance in *Rana pipiens*.[1]

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Introduction

The hatching of an amphibian embryo from its jelly capsule is aided by a hatching substance that is secreted by the embryo. The nature of this substance, sometimes called a hatching enzyme, has not been completely characterized although it has been shown to be heat labile (1) and to have a general proteolytic activity (4). This substance has been demonstrated in both urodele and anuran embryos (1, 3, 4, 5, 6, 7, 10) and acts by digesting a hole in the jelly capsule surrounding the embryo and thereby allows the wiggling embryo to escape.

It has been shown in an urodele, *Ambystoma opacum*, that the production of the hatching substance is restricted to the head region (6, 7). In this region there are unicellular epidermal glands that are large and intact prior to hatching but collapsed and empty after hatching. This phenomenon is true whether the hatching is natural or induced by treatment with pilocarpine. For this reason these cells have been given the name hatching gland cells.

Similar unicellular glands have been described in anurans (2, 11) but there has been no demonstration of a localized production of the hatching substance. The following experiments were performed to determine whether the hatching substance in *Rana pipiens* embryos is produced in a specific area or over the entire body surface.

Methods and Results

The basic approach taken in this work was to isolate portions of pre-hatch embryos, culture alike pieces together, and then determine if the media in which they were cultured contained any hatching substance. Hatching substance was detected by the ability of the culture media either to raise the vitelline membranes of gastrulae or to dissolve pieces of jelly capsule.

In the first experiment 70 pre-hatch embryos, Shumway stage 16 (8), were demembranated by removing all jelly capsules and membranes with watchmakers forceps. The embryos were then placed in full strength Steinberg's solution (9) containing antibiotics at the following concentrations: Elkosin 0.1%, streptomycin 0.04%, and penicillin 0.04%. (This solution from here on will be referred to as the standard solution.) They were then put through three washes of fresh standard solution by transferring them with a pipette from one watch glass of fresh media to another. The embryos were cut into quarters with iridectomy scissors as shown in Fig. 1. Alike quarters were put together in standard solution in petri dishes and allowed to sit for two hours in order to heal.

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[1] Contribution #780 from the Zoology Department, Indiana University.

[2] The author wishes to express his appreciation to Dr. R. Briggs for his helpful suggestions during the investigation.

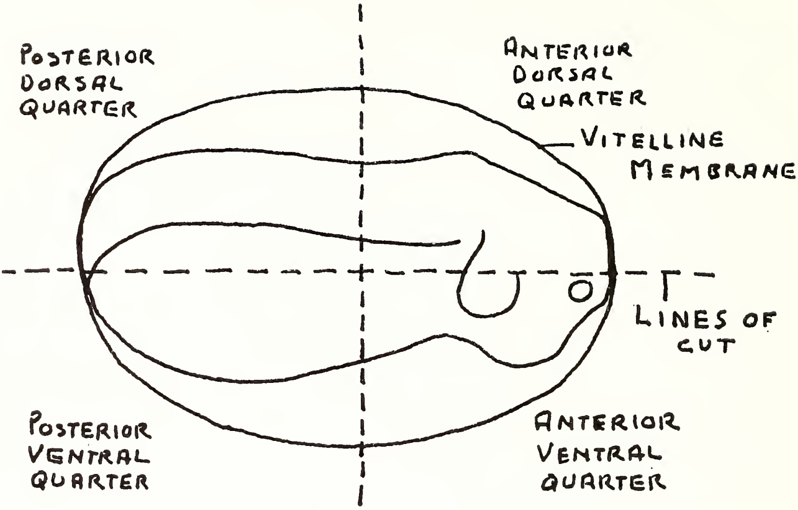

Figure 1. Stage 16 *Rana pipiens* embryo showing lines of cut and quarter designation in the first experiment.

They were then washed the same way as the whole embryos and finally placed in small plastic petri dishes containing standard solution. The volume in the dishes was adjusted to 3.2 ml. Seventy embryos from the same clutch of eggs were demembraned, washed, and placed in standard solution and the volume was adjusted to 4.0 ml. Twenty-one control embryos with membranes were put in standard solution. After 21 hours at room temperature, 22° C., the controls were at late stage 19 and all 21 had hatched. The producers, that is the demembranated whole embryos and the quarter embryos, were removed from their culture media 10 hours later. The petri dishes of culture media were stored at room temperature until 12 hours later when two stage 10 embryos (early gastrulae) were put in each of the five culture media and in some stand-

TABLE I

	3 hrs.	6 hrs.	9 hrs.	23 hrs.
Standard Solution	—	—	—	—
Whole Embryos	+	+	+	+
Posterior Dorsal	—	—	—	—
Posterior Ventral	—	—	—	—
Anterior Dorsal	—	±	+	+
Anterior Ventral	—	—	—	—

Results of observations in the first experiment on the ability of these solutions to raise the vitelline membranes of gastrulae. Time is from the time the gastrulae were placed in the solution. + indicates raising of membrane.

ard solution. The test embryos were checked periodically for raising of the vitelline membranes. The results are shown in Table I. From this it is apparent that the anterior dorsal quarter of the embryo is the only quarter producing any significant amount of hatching substance.

The second experiment was performed to localize, if possible, the area producing the hatching substance. In stages 16 and 17, just prior to hatching, the most anterior blunt end of the embryo is in direct contact with the vitelline membrane. An anterior view of the embryo (Fig. 2), shows a triangular shaped dark area which generally coincides with the area of contact. This area was considered, therefore, as a possible production site of the hatching substance.

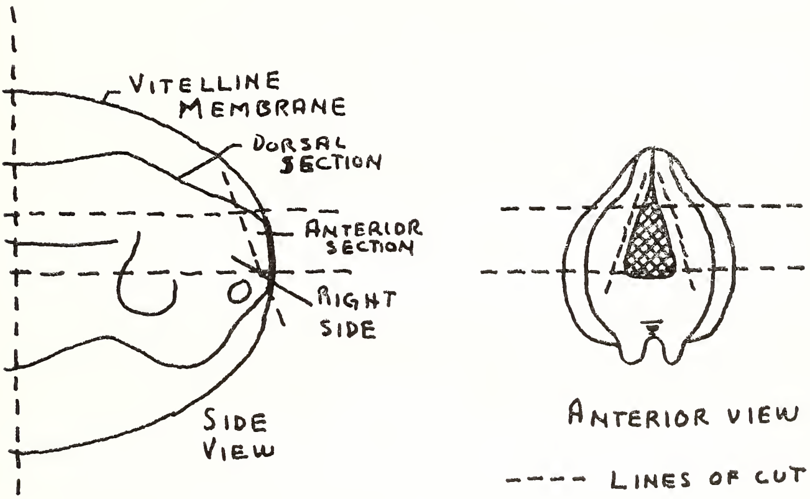

Figure 2. Stage 16 embyro showing dark area on anterior end and lines of cut in second experiment.

Ten stage 17 embryos were demembranated, quartered, and washed, as in the previous experiment, but only the anterior dorsal quarters were retained. These were then cut with glass dissecting needles, as shown in Fig. 2, and the following pieces were retained: the section containing the dark area, the right side, and the dorsal section. These were washed and alike pieces were put together in standard solution in a small depression in wax contained in a watchglass. It was felt that the manipulation of these small pieces of tissue would decrease their ability to function so the volume of media was kept as small as feasible. Each culture contained, therefore, between 0.02 and 0.03 ml. of standard solution. These small volumes precluded the use of gastrulae as test subjects. Instead, small pieces of jelly capsule, taken from the experimental embryos during demembranation, were placed in the cultures along with the pieces of tissue. A fourth culture of jelly capsule alone in standard solution was set up in the watchglass. The softening or solution of the pieces of jelly capsule would indicate the presence of the hatching substance. The watchglass was then put in a moist-chamber to prevent evaporation.

Twenty-one control embryos with membranes were put in standard solution and these and the cultures were left at room temperature, 25° C. The pieces of jelly capsule were checked periodically for softening. The results are shown in Table II. At 13 hours all of the control embryos were at early stage 19 and had hatched. From these results it can be concluded that the hatching substance is produced in the most anterior region containing the dark area and probably to a lesser extent along the dorsal part of the embryo.

TABLE II

	13 hrs.	19 hrs.
Standard Solution	—	—
Right Side	—	—
Anterior	±	+
Dorsal	—	+

Results of observations in the second experiment on the ability of these solutions with their producers to dissolve pieces of jelly coat. Time is from time of placement of embryo tissue and jelly coat in the solution. + indicates softening or solution of the piece of jelly capsule.

Discussion

The results of these experiments agree with the work previously done with *Ambystoma opacum* (6, 7) and go further in showing a relatively restricted region of production which coincides with a visible landmark on the embryo. The descriptions of the distribution of hatching gland cells in certain anurans indicate that most of the cells are located in this frontal area and to a lesser extent along the dorsal midline (2, 11). If it is assumed that the distribution of the hatching gland cells in *R. pipiens* is similar to that described for other anurans then there appears to be a correlation between the demonstrated production site and the distribution of the hatching gland cells. Obviously histological work should be done to determine the location of these cells in *R. pipiens*.

Summary

Pre-hatch embryos were stripped of their jelly capsules and membranes and cut into quarters, or smaller sections, and alike pieces were cultured together. The culture media were then tested for hatching activity by determining their ability either to raise the vitelline membranes of gastrulae or to dissolve pieces of embryo jelly capsule. From the results of these experiments it was concluded that the hatching substance was produced mainly in the most anterior portion of the embryo and to a lesser extent along the dorsal midline.

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An Analysis of Pupal Proteins of *Drosophila melanogaster* by Polyacrylamide Gel Electrophoresis

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Introduction

The classical object of genetic study, *Drosophila melanogaster*, provides a desirable system for studying biochemical events related to differentiation: these Dipterans may be grown in synchronous culture, a wealth of genetic information exists about them and the life cycle is relatively short. The dearth of Drosophila biochemical genetics has recently been discussed (2). The demonstration of protein differences with respect to age is a proper part of a study of developmental processes. This report includes a description of the methods employed, the results of the analysis of various pupal ages and a short discussion of the results.

Methods and Materials

Rearing of Pupae

The stock used in all experiments was Oregon R-C (obtained from Dr. E. B. Lewis). An egg-producing population was maintained at 25 ±0.5°C in a lucite cage (40″ x 50″ x 55″) and fed daily on 10 cm plastic petri plates of standard banana-agar medium topped with a thick suspension of active yeast. In order to stimulate the laying of stored eggs, these feeder plates were changed two hours before egg collections were begun. Half-pint milk bottles containing about 35 ml of banana-agar medium topped with yeast were inserted into the population cage and then incubated at 25 ±0.05°C until the pupae were ready for collection. Pupae were collected by filling the bottles with tap water, loosening the pupae from the walls with a camel's hair brush and pouring the floating pupae onto a kitchen strainer. The pupae were then resuspended in water and washed several times until the wash water was clean. The pupae were allowed to dry on paper toweling, weighed and incubated until the age needed for experimentation. At the proper time the pupae were stored at —65°C.

Homogenization and Centrifugation

The pupae were homogenized in first distilled water in a Kontes glass cone grinder driven by a stirring motor. The homogenization volume was 2.5 x the weight of pupae (ml/gm); the homogenizer was rinsed with an aliquot 1.5 times weight of pupae (ml/gm). The homogenate is brown and viscous but can be drawn up in a machine-manufactured capillary pipette. The homogenate was centrifuged at 45,000 rpm (average force = 122,249 x g) for 30 minutes at 4°C in a model L Spinco centrifuge (type 50 rotor). Centrifugation yields a granular dark brown sediment covered by a whitish middle layer and a yellow-brown supernatant with a pellicle of lipid on its surface. The lipid layer is removed and the supernatant is used directly for electrophoretic analysis. The supernatant was stored at —65°C; electrophoresis of stored supernatants (6 weeks) gives results identical to fresh preparations.

Electrophoresis

Polyacrylamide gel electrophoresis was done on an apparatus constructed from two plastic wash basins supported on a plyboard rack. The method of electrophoresis was that of Ornstein (3) as modified by Davis (1). Figure 1 shows the basic relationships of the gel which is polymerized inside glass running tubes (5.3 cm, 5 mm i.d. tubing). A constant current of 5 milliamperes was provided by a Beckman Duostat power supply for about forty minutes at 4°C. The run was stopped when the tracking dye band had proceeded to about 0.5-0.75 cm from the bottom of the tube. The gels were loosened by rimming the ends with a dissection needle and were then forced out by hydrostatic pressure from a medicine dropper bulb. The gels were cut off at the tracking dye band and immersed in Amido-Schwarz stain for one hour or more. The samples were destained electrophoretically in 15% HOAc at 15 ma per tube. The destained gels were stored in 7½ percent HOAc.

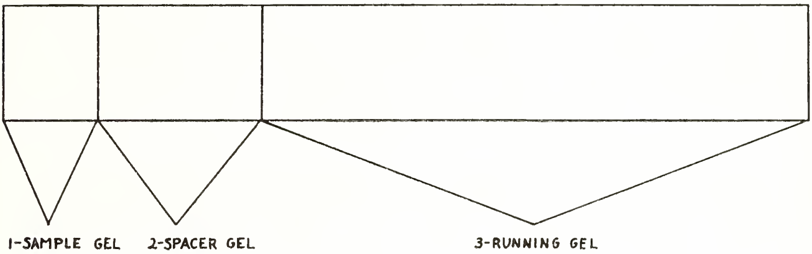

Figure 1

Results

About 25 bands were obtained. A composite diagram of the bands is shown in Figure 2. The majority of the bands did not change during th pupal stage; some changes were observed, however. The following results were obtained:

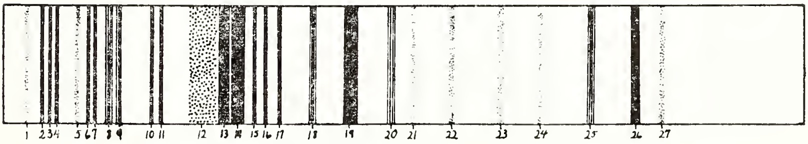

Figure 2

Bands 1-7	Constant
Band 8	Reddish staining band; appears at 132 hours, strongest at 150, fades and disappears by 174.
Band 9	Constant.
Bands 10-11	Did not always separate.
Bands 12-14	Constant.

Bands 15-18	Bands 15 and 16 may be the same. Bands 17 and 18 grow stronger from 168-192 hours.
Bands 19-24	Constant.
Band 25	Weak until 144; then becomes much stronger and persists through to the end of the pupal stage at 192 hours.

Discussion

These results show that the major protein components of the pupal stage do not vary greatly. Thus, few proteins which are involved in metamorphosis probably can be detected by this method. Some bands (8, 17, 18, 25) may provide useful systems for study. Other experiments that are pertinent to this work could concern the analysis of various Drosophila mutants. These data may serve as a reference for future studies on Drosophila pupae proteins particularly protein synthesis.

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Lipid Metabolism in the Mediterranean Meal Moth *Ephestia kühniella* Zeller During Its Life Cycle.[1]

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Introduction

The nature of the fuel reserves required for embryogenesis, metamorphosis and flight metabolism in many insect orders has been relatively well elucidated (14, 20). On the other hand fewer workers have investigated the energy reserves required for embryogenesis (2) and flight metabolism (3, 22) in the Lepidoptera, and those concerned with the relationship between the energy expended during the post-embryonic phase of the life cycle and the organic fuels catabolized during this phase have been indeed sparse. In this paper the Mediterranean meal moth, *Ephestia kühniella* Zeller, is studied. By the analysis of total lipids, non-esterified and total fatty acids, together with manometric determination of respiratory quotients, meal moth metabolism during development could be characterized.

Materials

Mediterranean meal moths were reared according to the directions of Whiting (19). The insects were fed degerminated yellow corn meal consisting of water, 12%; protein, 8.3%; fat, 1.2%; ash, 0.5%; carbohydrate, 78%; and fiber, 0.7% (13). Insects were kept in a constant temperature cabinet at 24 ±1° C. Relative humidity was maintained at 50-60 percent.

No attempt was made to use a genetically homogeneous meal moth population in this study. This heterogeneity may have been responsible for the considerable variations existing between the chronological age of the insects and their physiological and morphological development. Other investigators (cf. 10) have also noted an erratic time sequence of meal moth development despite the fact that external factors (temperature, light, relative humidity, population density, and availability of food) were carefully regulated. Therefore, the larvae of the insects were arbitrarily divided into stages according to fresh weight (4, 7).

Non-feeding prepupae were detected by the presence of an external cocoon and especially by the white color of the abdomen following complete elimination of fecal material (12). Pupae were considered as a single developmental stage. Adults were studied on the first, second, and ninth day after emergence.

Methods

Larval, pupal, and adult respiration were followed for periods of one hour in Warburg constant volume respirometers having a capacity of about 7 ml. The exact volume of the flasks containing insects and, in the case of larvae, their corn meal diet, was determined by the method of Hoopingarner and Beck (11). Data on oxygen consumption and carbon dioxide production were calculated by the "total uptake method" (18). All experiments were carried out at 25° C. in a constant temperature water bath. Animals at various stages of development were anesthetized with carbon dioxide (21), weighed on a Roller-Smith precision balance, and then placed in the main compartments of the respirometers; six vessels, not including the thermobarometer, were set up, three with 0.2 ml. of 10% KOH in the center wells and three without KOH in the wells. The average oxygen consumption calculated for the former was used in determining the CO_2 production of the latter. By comparison of these two parameters respiratory quotients were obtained which enabled the proportion of calories derived from fat and carbohydrate to be determined (6). The calorific values in Carpenter's Table were applied directly to the measured respiratory exchange without separately computing the protein catabolized.

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[1] From a thesis submitted in partial fulfillment of the requirements for the Ph.D. degree at Brown University.

Determination of changes in water concentration during development were made by weighing the insects before and after complete drying at 80° C. Batches of desiccated insects were subsequently used for lipid determination. Lipid, estimated as the total petroleum ether extractable material, included neutral fats, fatty acids and other ether-soluble material (8). The dried organisms were kept at 28° C. for 48 hours in tubes with 5 ml. of petroleum ether which was changed several times. They were then dried and reweighed. Thus, the weight of ether-soluble material was given by subtraction and not by direct weighing of the extract. Extraction for longer periods of time did not increase the amount of ether-soluble material.

Analyses for esterified (EFA) and non-esterified (FFA) fatty acids were carried out on larval and prepupal hemolymph. The insect was punctured with a glass needle and the fluid collected was added immediately to an extraction mixture: for EFA the extraction mixture was ethanol-ether (3:1); for FFA it was 1N H_2SO_4 (0.1 vol.), heptane (1 vol.) and isopropyl alcohol (4 vol.). Esterified fatty acids were determined by the method of Stern and Shapiro (16) using triacetin as the standard. Dole and Meinertz' (9) method, slightly modified, was used for the microdetermination of non-esterified fatty acids; recrystallized palmitic acid was the standard. In both analyses, EFA and FFA, 10-40 μl of hemolymph gave reproducible results.

Results

At 25° C. and 50-60 pecent relative humidity the weight range of the meal moth is from 0.021 mg. for the egg to about 27 mg. for the late sixth instar larva (Table I). The earliest larval stage weighs little more than the egg but weight gain is rapid, the early instars almost doubling their weight between molts. Non-feeding prepupae lose weight, as do the non-feeding pupae and adults. From the first day of emergence until the ninth day, both male and female adults lose 50 percent of their fresh weight; females, at all times, weigh more than males of corresponding age.

TABLE I

Changes in Weight and Water Concentration During the Meal Moth Life Cycle.

	Weight		Average Water Concentration	
Stage	Number of Insects	Average Weight per Insect mg.	No. of expts.	% wet weight
Egg	715	0.021	1	69.5
Larva				
Hatchling	45	0.025	1	62.5
Instar 1	21	0.080	1	61.7
Instar 2				
Early	62	0.256	2	65.5±2.21[1]
Late	88	0.752	1	69.1
Instar 3	82	1.94±0.013[1]	5	69.4±1.87
Instar 4				
Early	32	3.52±0.195	3	69.5±2.92
Late	31	5.43±0.174	3	74.6±1.03
Instar 5				
Early	75	12.27±0.321	14	68.9±0.505
Middle	35	16.37±0.482	11	67.3±1.33
Late	44	19.09±0.187	13	66.8±0.878
Instar 6				
Early	68	20.93±0.300	4	66.9±0.364
Late	10	26.81±0.480		
Prepupa	13	19.45±0.308	7	66.3±0.538
Pupa	32	15.31±0.806	15	68.4±1.83
Adult				
1 day old				
virgin female	3	13.39	1	68.0
male	3	9.11	1	69.2
2 day old				
female	3	9.30	1	65.7
male	3	7.04	1	56.3
9 day old				
female	3	6.04	1	63.1
male	3	4.88	1	61.1

[1] Standard error of the mean.

The average water concentration of the meal moth is rather constant throughout the life cycle (Table I), varying from about 66-69 percent of the fresh weight. Only the two earliest larval instars, the two-day-old adult male, and the nine-day-old adult male and female show values considerably lower than these.

Table II illustrates the changes in oxygen consumption and carbon dioxide production during the life cycle of the meal moth. The QCO_2 of the early fifth instar larva is relatively high, having a value which is about four times that of the prepupa and seven times that of the pupa. A similar relationship between the early fifth instar larva and the prepupa and pupa is noted for the QO_2. For both metabolic parameters the gas exchange values of the other developmental stages are not significantly different from each other.

TABLE II

Oxygen Uptake, Carbon Dioxide Production, Respiratory Quotients, and Approximate Contribution of Carbohydrate and Fat to the Total Amount of Energy Transformed During the Meal Moth Life Cycle.

Stage	No. of expts.	Gaseous Exchange CO_2[1]	O_2[1]	Respiratory Quotient	Energy Derivation Fat %	Carbohydrate %
Larva						
Instar 4	1	3.91[2]	3.62	1.08		
Instar 5						
Early	16	3.63 ± 0.42[3]	4.23 ± 0.61	0.906 ± 0.027	30.6	69.4
Middle	25	2.19 ± 0.24	2.56 ± 0.29	0.858 ± 0.023	47.6	52.4
Late	29	1.73 ± 0.15	1.97 ± 0.17	0.888 ± 0.019	37.4	62.6
Instar 6						
Early	14	2.14 ± 0.42	2.50 ± 0.46	0.841 ± 0.012	54.4	45.6
Late	10	1.51 ± 0.19	1.59 ± 0.17	0.941 ± 0.040	20.4	79.6
Prepupa	15	0.792 ± 0.07	1.10 ± 0.13	0.720 ± 0.018	95.2	4.8
Pupa	16	0.520 ± 0.04	0.640 ± 0.07	0.782 ± 0.033	74.8	25.2
Adult	3	1.62 ± 0.15	1.90 ± 0.16	0.854 ± 0.041	51.0	49.0

[1] μl./mg./hr.

[2] Mean

[3] Standard error of the mean

Respiratory quotients are also given in Table II. The value for a single determination on fourth instar larvae is 1.08. Fifth and sixth instar larvae and the adults do not differ significantly. The prepupae and pupae, however, have considerably lower respiratory quotients, 0.720 and 0.782, respectively. Thus, from Carpenter's (6) Table 13, which gives the approximate proportion of calories derived from carbohydrate and fat for each respiratory quotient (Table II), it would seem that the prepupae and pupae draw most heavily on lipids as a source of energy.

The absolute lipid content of individual meal moths increases steadily during development until the sixth instar, being then followed by a decrease in the non-feeding prepupae, pupae, and adults (Table III).

TABLE III

Changes in Petroleum Ether-Soluble Material During the Meal Moth Life Cycle.

Stage	No. of expts.	Ether-Soluble Material mg./animal	% dry wt. (mean±S.E.)	% wet wt. (mean±S.E.)
Larva				
Instar 1	1	0.004	13.0	4.8
Instar 2				
Early	2	0.022	24.60±0.142	8.50±1.06
Late	1	0.033	17.80	5.52
Instar 3	4	0.099	18.53±3.35	5.97±1.62
Instar 4				
Early	2	0.311	24.15±3.35	7.86±2.48
Late	3	0.362	24.22±2.52	6.39±0.384
Instar 5				
Early	13	1.58	44.86±2.76	13.09±1.74
Middle	10	2.49	48.46±2.11	15.11±1.19
Late	12	2.49	49.44±1.50	17.33±0.690
Instar 6	4	3.78	47.80±2.98	15.91±1.22
Prepupa	7	2.56	38.16±1.69	12.94±0.678
Pupa	10	2.27	43.02±2.06	14.84±1.05
Adult				
1 day old				
virgin female	1	1.67	39.4	12.6
male	1	1.24	44.00	13.6
2 day old				
female	1	2.11	43.6	22.7
male	1	1.35	44.2	19.3

Instars 2, 3, and 4 have essentially the same percentage of total lipid. This percentage is doubled in Instars 5 and 6, in the pupa, and in the adults.

The esterified fatty acid concentration (Table IV) of the hemolymph of fifth and sixth instar larvae, 442 mg% and 392 mg%, respectively, is not significantly different, while that of the prepupa reaches a considerably higher level (820 mg%). Free fatty acids increase less markedly from the fifth instar larva to the prepupa; the concentration in the latter, however, is significantly different from that of the former.

TABLE IV

Changes in Hemolymph Free and Esterified Fatty Acids During the Meal Moth Life Cycle.

	Esterified Fatty Acids		Free Fatty Acids	
Stage	No. of expts.	mg. % (mean ± S. E.)	No. of expts.	mg. % (mean ± S. E.)
Instar 5	2	442.50 ± 76.50	5	68.82 ± 6.02
Instar 6	12	392.08 ± 34.01	1	90.80
Prepupa	4	820.25 ± 53.00	4	108.51 ± 16.32

Discussion

In developing insects changes in blood composition reflect the morphogenetic and biochemical transformations taking place in the tissue (5). Arnold (1), the only other worker that we are aware of who reported on blood lipids in relation to developmental processes in *Ephestia kühniella*, noted that the concentration of hemolymph lipid was low in the early larval stages; lipid concentration increased as pupation approached, reaching a maximal value in the prepupal period. Our data (Table IV) on EFA and FFA values in developing insects substantiate these findings. Feeding meal moths show relatively low hemolymph FFA and EFA concentrations, while non-feeding—or starving—animals (prepupae) show higher concentrations. Both FFA and EFA have been implicated as the transport form of fatty acids; hence, their concentration should rise when the starving insect is called upon to utilize lipid as its primary energy source. Arnold (1) further found that after the onset of pupation the lipid content of the hemolymph declined rapidly. His data suggest, as do ours, that *Ephestia* can synthesize fats from dietary carbohydrates and/or protein. Our animals were maintained on a diet consisting of 78 percent carbohydrates, 8.3 percent protein and only 1.2 percent fat. Still, the evidence indicates that meal moth larvae stored lipid for oxidation in the advanced developmental stages, the prepupae and pupae. Stages other than the prepupae and pupae oxidized both lipid and carbohydrate, with the greater proportion of energy being derived from the latter.

Total lipids constitute over 40 percent of the dry weight of Instars 5 and 6 and about 20 percent of the dry weight of Instars 2, 3, and 4. [Scroggin and Tauber (15), reporting on Timon-David's data for an unspecified larval instar of *Ephestia figulilella*, noted that 21.4 percent of the wet weight of this species was lipid; lipids account for 4.8 to 17.33 percent of the wet weight of *E. kühniella*.] About 43 percent of the pupal dry weight was lipid; in the prepupa the corresponding value was 38 percent.

The average Q_{O_2} for the inactive pupa was 0.640 μl./mg./hr., while the Q_{CO_2} was 0.520 μl./mg./hr. Using single meal moth pupae Taylor (17) measured oxygen consumption from 30 hours after pupal case formation until the emergence of the adults (about 260 hours at 25° C.). He noted the typical U-shaped curve for pupal oxygen consumption, with a minimum Q_{O_2} of from 0.25 to 0.35 μl./mg./hr. for males and females to 0.700 to 0.800 μl./mg./hr. for males and 0.850 to 1.000 μl./mg./hr. for females. Thus, the Q_{O_2} of 0.640 μl./mg./hr. reported in this paper, while not taking into consideration developmental variation, represents an average pupal oxygen uptake which is in agreement with Taylor's (17) data.

The relation between CO_2 produced and O_2 consumed represents only the summation of the processes of synthesis and breakdown that are going on throughout metamorphosis. Hence, such analyses of the whole animal should not be interpreted uncritically. Still the R.Q. values of about 0.9 noted in meal moth larvae probably indicate that the bulk of the energy for development was derived from carbohydrates, with a lesser contribution from lipid; this is consistent with the efficient utilization of corn meal. Non-feeding prepupae and pupae, on the other hand, show a marked lowering of the R.Q. to 0.720 and 0.782, respectively, indicating increased oxidation of substantial amounts of lipid. Finally, the adult respiratory quotient of 0.854 may represent a mixed catabolism.

Summary

1. The average water concentration of the meal moth was rather constant throughout the life cycle, varying from 66 to 69 percent of the fresh weight.

2. The rates of oxygen consumption and carbon dioxide production followed similar U-shaped curves. Throughout larval development respiratory exchange, initially relatively high, declined, reaching a minimum when activity ceased during the last larval, or the prepupal, period. The rate then dropped further in pupal life, rising again to an adult level that was near the level attained by the early sixth instar larva.

3. The earliest larva studied had an R.Q. of 1.08. The prepupal and pupal respiratory quotients, 0.720 and 0.782, respectively, were considerably lower than the other stages observed.

4. Instars 2, 3, and 4 contained essentially the same percentage of ether-soluble material (about 20 percent of the dry weight); this value was doubled in Instars 5 and 6, in the pupa, the prepupa, and in the adults.

5. The esterified fatty acid content of the hemolymph of fifth and sixth instar larvae, 442 mg% and 392 mg%, respectively, was not significantly different, while that of the prepupa reached a considerably higher level.

6. Free fatty acids increased less markedly than EFA from the fifth instar larva to the prepupa.

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The Problem of Toxicity in *Rana palustris*

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The person most responsible for the claims of toxicity in the pickerel or marsh frog, *Rana palustris,* is Albert Hazan Wright. In publishing alone (7, 8) and with his wife Anna Allen Wright (9, 10), he constantly refers to toxicity in *R. palustris.* The Wrights observed the following: (1) dogs and snakes demonstrating great discomfort after grasping pickerel frogs with their mouths; (2) amphibians confined with *R. palustris* dying before their container was carried from the collecting area to the laboratory.

These claims were amplified by the following: (1) Walker (6) mentioned that pickerel frogs were rejected as food by garter snakes (genus *Thamnophis*). He attributed this effect to the acrid skin secretions of *R. palustris.* (2) Conant (2) noted that few snakes will eat the marsh frog. He claimed that the distasteful secretions of skin glands were responsible. (3) Pope (4) speculated that toxicity confers upon *R. palustris* an immunity to predation which allows it to survive in snake infested areas where other frogs would perish. (4) Cockran (1) warns about placing other frogs in the same vivarium as *R. palustris,* due to its supposed toxicity.

Despite this evidence, Pope (4) and Smith (5) thought there was need for additional proof before the claim of toxicity could be accepted. In addition, Manion and Cory (3) contradicted most of the previous evidence. They found that a year-old snake of genus *Thamnophis,* when presented with live *R. palustris,* on successive days "eagerly seized and swallowed *R. palustris.*" It was also noted by Manion and Cory that the record of *R. palustris* being present in Livingston County, Michigan, indicates that the frog was found in the stomach of a garter snake.

The following quote from the dissertation of Manion and Cory (3) demonstrates that *R. palustris* is not toxic to other amphibia.

> "On two occasions individuals of this species (*R. palustris*) were closely confined with other frogs. . . . In one case, 2 individuals with 1 *R. clamitans* in a two-quart jar; in the other case, 8 *R. palustris* with 3 young *R. catesbeiana,* 4 *R. clamitans* and 2 *R. pipiens* in a 17 x 9 x 9 inch aquarium. In both cases, *R. palustris* was first to succumb under crowded conditions. All 10 individuals of this species died before any of the others, with the exception of the *R. clamitans* in the 2-quart jar, and even in this case the 2 *R. palustris* died first."

The following experiments were designed to test the question of toxicity in *R. palustris.* The non-toxicity demonstrated by Manion and Cory with 10 *R. palustris* associated with 10 other amphibia, was confirmed using over 100 adult *R. palustris,* 2 dozen other amphibia and more than 250 larvae.

The experimental animals were kept in a 4 gallon aquaria. One end of each aquarium was raised 30 degrees, and approximately 1¼ liters of tap water was included. A paper towel placed over the area of the aquarium floor not covered by water became saturated through capillary action, and enabled the animals to climb out of the water. The larvae remained in the water which was shared by the adults. Control larvae were kept in 8″ diameter finger bowls in an amount of water equal to that in the aquaria.

TABLE I

Association of *R. palustris* Adults with Adults of *R. pipiens* and *Notophthalmus viridescens*

Group	Species	Number of Adults	Mortality in 30 Days
I	*R. palustris*	97	26%
	R. pipiens	15	20%
II	*N. viridescens*	9	0%
	R. palustris	56	4%
III	*N. viridescens*	6	0%

Table I shows three groups. The first group includes single adult *R. pipiens* maintained for at least a month in the same tank with as many as twenty Michigan, Massachusetts or Wisconsin *R. palustris*. Eighty percent of the *R. pipiens* survived, a six percent higher survival than the *R. palustris* with which they were associated. This result would have been impossible if *R. palustris* was toxic to *R. pipiens*.

In the second group, single *Notophthalmus* (= *Triturus*) *viridescens* were kept with some of the same *R. palustris*. Over a period of more than thirty days' exposure all salamanders survived, as did their controls, group three.

TABLE II

Survival of *R. pipiens* Larvae Associated with *R. pipiens* and *R. palustris* Adults

Species of Adults	Number of Adults	Number of Larvae	Initial Larval Length	Larval Mortality After First Day	Larval Mortality After 120 Days
R. palustris	39	67	11-20 mm.	3%	15%
R. pipiens	26	56	11-20 mm.	2%	2%
Control	0	43	14-20 mm.	0%	51%

A test for toxic effect on ranid larvae was devised (Table II). *Rana pipiens* larvae were raised under three varying conditions: (1) with *R. pipiens* adults (non-toxic), (2) with *R. palustris* adults (said to be toxic), (3) in finger bowls (as an experimental control). In the last two columns, Table II lists the number of larvae which were found dead and could possibly be considered as toxicity victims. Larvae which were cannibalized or crushed by the adults were not included in this total, since it is not likely that they could have been poisoned.

In order to be killed in either of these fashions, the larvae would have to be swimming in the shallow water near the basking area of the adults. Larvae killed by poison or congenital defects would sink to the bottom of the slanted floor. If they had been poisoned their lack of activity could not incite a feeding reaction in the adults, thus they must have been alive and in reach. Therefore those larvae eaten or crushed were not considered as being poisoned.

Should there have been a strong toxin secreted by the *R. palustris* adults, many larvae would have been found after the first day of contact with the marsh frogs. Such was not the case. Through the course of the next 120 days very few larvae were ever found dead, let alone in a condition which could be interpreted as a toxic effect. The total larval mortality, including deaths through cannibalism and injury, is represented in Figure I. In case of *R. pipiens* larvae associated with *R. pipiens* adults, there is an immediate reduction in the number of survivors. Yet *R. pipiens* adults are not known to be toxic and could hardly be thought to poison their own species. The rapid decline of the larvae can only be attributed to injuries they received from the bulky adults.

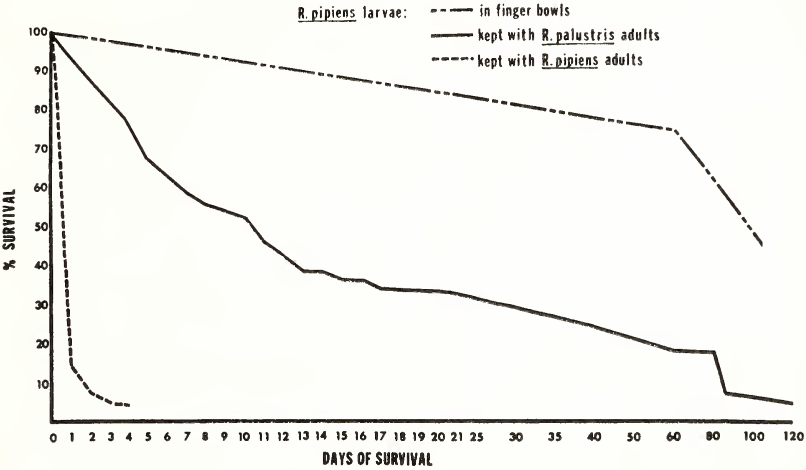


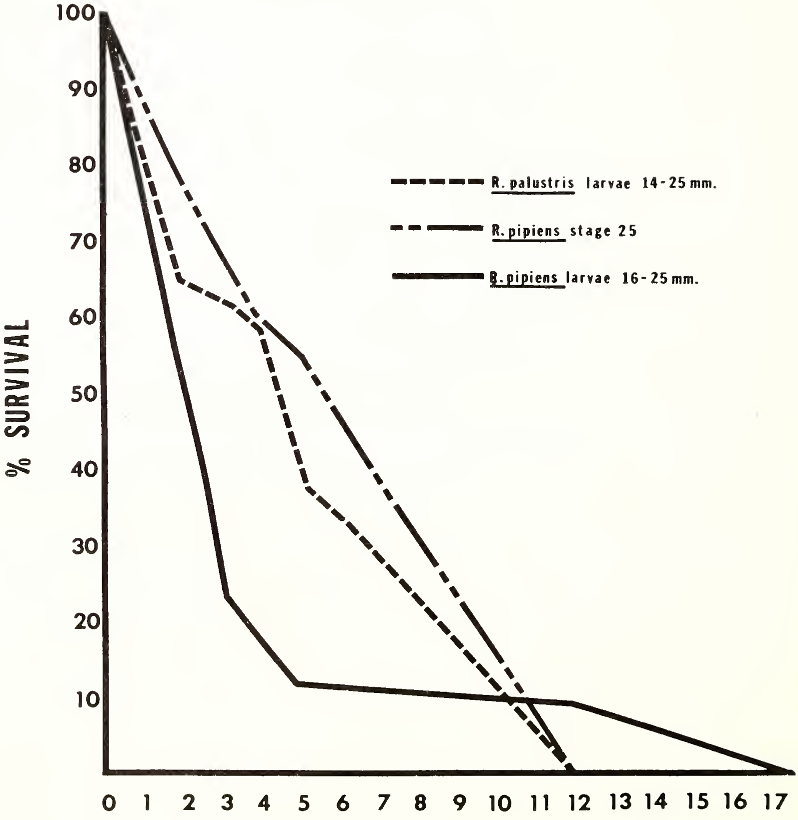
Figure 1

Those *R. pipiens* larvae associated with *R. palustris* adults were far from being decimated. There was no initial dip in the survival curve which would indicate a strong toxic effect. Sixty percent of the larvae survived for at least a week. Close to thirty-five percent were alive after 20 days. Between fifteen and five percents lasted from 80 to 120 days in an environment which was supposedly toxic. Any decline in the experimental as compared with the control survival rates can be explained by the effect of (1) some degree of jostling, which was not as great as in the case of the more bulky *R. pipiens* adults; (2) cannibalism on the part of the *R. palustris* adults. (Photographic evidence of cannibalism was presented at the October meetings.)

TABLE III

Survival of Tadpoles Associated with Adult *R. palustris*

Species of Larvae	Number of Larvae	Number of Adults	Larval Mortality After First Day	17 Days
R. pipiens (11 mm.)	60	31	0%	12%
R. pipiens (14-25 mm.)	43	52	0%	5%
R. palustris (16-25 mm.)	40	52	0%	3%



DAYS OF SURVIVAL OF LARVAE
ASSOCIATED WITH R. palustris ADULTS

Figure 2

When compensation is made for cannibalism and injury the survival curves of adult associated larvae approach that of the control, making the claim of toxicity less tenable.

Another comparative experiment is represented in Table III and Figure II. Two types of larvae were associated with *R. palustris* adults: those of *R. pipiens* which should have been poisoned, and those of *R. palustris* which should not. In Table III it is again noted that throughout the experiment, few larvae were ever found dead. Initial contact with the adults produced no suspected toxicity victims. After 17 days, less than 9% of the total *R. pipiens* larvae could be remotely considered as poison victims. Examination of the total survival of the two *R. pipiens* age groups and one *R. palustris* larval group, shows that the decline of the *R. palustris* larvae fell well within the variation between the two leopard frog survival curves. Had there been a difference in the survival rates based on susceptibility to toxin, there would have been a greater divergence of the *R. palustris* curve from the other two. It seems that the decline throughout all these experiments could be attributed to cannibalism and crushing, which applied to each larval species to the same extent.

A subsequent experiment investigated the extent to which cannibalism and physical injury, increased the mortality rate of adult associated larvae. Small numbers of *R. pipiens* larvae of the same size range, age and health were divided into three groups. One was placed in the tank water with adult *R. palustris*. The second group was placed in 250-300 ml. Erlenmyer flasks, sealed with highly porous cheese cloth. The flasks were then placed into the tank allowing free exchange of water between tank and flask. The third group was kept in finger bowls completely isolated from the adults. The number of larvae totally exposed to adults was reduced through physical injury or cannibalism, whereas those flask-enclosed larvae survived at a rate which approached that of the controls.

After experiments in which *R. palustris* were associated with other amphibia in different phases of their life cycles, there was no demonstrable toxicity on larval and adult amphibia of other species. These results do not support the theory of pickerel frog toxicity.

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Some Factors Affecting the Toxicity of Aldrin to Fishes

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Aldrin is quite toxic to fishes, though not the most toxic of the insecticides. A table from Henderson, Pickering, and Tarzwell (2) shows that a .026 ppm aldrin solution will kill half of a sample of fathead minnows in 96 hours at 25 degrees C. The same table shows that endrin is about twenty times as potent, and that DDT is not quite as lethal as aldrin. Tarzwell and Henderson (4) showed that a related compound, dieldrin, was more toxic to fathead minnows than to equal-sized bluegills or green sunfish. Pickering, Henderson, and Lemke (3) ascertained that small bluegills were more susceptible to organic phosphorus insecticides than were large bluegills; they showed, too, that bluegills were more sensitive than fatheads, guppies, and goldfish to both organic phosphorus and chlorinated hydrocarbon insecticides of various kinds.

Some general symptoms of aldrin poisoning are as follows: As the poison takes effect, the fish become very irritable. When stimulated by a slight sound, by agitation of the water, by turning on an electric light, or simply by a movement nearby, they often dash wildly or swim in circles. The dash sometimes ends in a state of shock, with the gills motionless and distended, from which the fish may die almost at once or may partially recover and live on for hours or days. A few of the larger fish injure themselves by bumping violently into the sides of their containers. Aldrin-poisoned fish also have a tendency to gulp air at the surface, as if they were suffering from lack of oxygen.

In at least one fish, the brindled madtom (*N. miurus*), it seems very likely that respiratory failure brings about death somewhat before other toxic effects have progressed to the point of lethality. I watched two madtoms apparently die; they became quite motionless and their gills were distended. I placed them in a shallow tray with ¼ inch of fresh water so that their backs were exposed to the air, and they revived. Three days later, the two fish seemed quite healthy. But within minutes after I had placed one in deep water, it was gulping at the surface, and within an hour it was dead. The other madtom shortly thereafter developed a swollen red area on its abdomen from its gills to its anal fin, and also succumbed.

Some fishes seemingly recover from rather large doses of poison. One large spotfin shiner (*N. spilopteris*) was removed to fresh water when it became the last one of 91 minnows of that species to remain alive. It was observed for two months afterward, during which time it remained without observable symptoms. (This does not preclude possible chronic physiological changes.)

Also, I had occasion to observe that the symptoms of fishes differ to some extent from those of large aquatic insects (hellgrammites, dragonfly nymphs, and adult water scorpions) and crayfish. These invertebrates all seemed to very gradually lose their powers of locomotion and just fade away, whereas fish were able to balance themselves and swim almost until they died. Two adult crayfish outlived the fish in an experiment in a five-gallon aquarium, but they had reached the stage where their legs waved aimlessly; they lived on for 8 and 17 days in fresh water without recovering their locomotor ability. Five of six dragonfly nymphs died within a few hours of the time the median fish death occurred in a 275-fish experiment. At about this same time an adult water scorpion seemed normal and was making efforts to capture food; it died at about the same time the 220th fish died. Two hellgrammites also died at about the same time.

My intention had been to perform the study according to a standardized procedure developed by Doudoroff *et al.* (1). In this procedure a series of aquariums containing different dosages of the poison being tested is used to establish a median tolerance limit (the elapsed time at which 50% of the fish have died). I found, however, that I did not have enough aquariums to carry the work forward on a satisfactory scale and also that I was unable to exercise sufficient control over the temperature to allow comparison between any tests that were not run concurrently.

As a preliminary measure, I sought to determine for myself the approximate minimal dose of aldrin that would produce short-term fatality. With the limits imposed by my lack of control over the temperature, I confirmed the results of Henderson *et al.* (2) as follows: Fifteen liters of water and 10 small (average length 1½ inches) common shiners were placed in each of two aquariums. After three days, aldrin was added in sufficient quantity to make a .02 ppm concentration in one aquarium and .08 ppm in the other. In the .02 ppm aldrin, only one minnow died within 96 hours; in the .08 ppm aldrin, the sixth minnow died at 52 hours. Neither aquarium was aerated artificially. The water was cold, ranging from 9 to 14 degrees C. I re-ran this experiment, using aquarium heaters to keep the temperature over 20 degrees C. Again, only one of ten common shiners died in the .02 ppm concentration. The median death in the .08 ppm aldrin was at 12 hours, a much smaller figure than in the test with colder water. In either case, the 96-hour median tolerance limit was fixed at between .02 and .08 ppm.

Though temperature has one of the more obvious effects upon survival time, as noted above, and as was recognized by Doudoroff, I ran one more test with temperature as the experimental factor. In this test, I again used 15 liters of water in each of two aquariums. Enough aldrin was added to form a 1 ppm concentration. The fish used were half-grown redfin and common shiners (*N. umbratilis* and *N. cornutus*). The water temperature in one aquarium ranged from 13 to 16 degrees C. with the median death occurring in 12 hours. In the other aquarium (heated), the temperature reached 24 degrees with the median death occurring in 5½ hours. (In each aquarium, the average survival time of the redfin shiner was slightly longer than that of the common shiner; the redfins were comparatively more mature, however, in spite of the similar sizes, and this could account for the difference.)

Minerals dissolved or suspended in water have been shown by Tarzwell and Henderson and by Pickering, Henderson, and Lemke to have at least a slight effect upon the toxicity of insecticides to fishes. I made an attempt to verify this, using pond water (total alkalinity 80 ppm, total hardness 74 ppm), creek water (total alkalinity 290 ppm, total hardness 910 ppm), well water (total alkalinity 600 ppm, total hardness 0 ppm), and distilled water (not analyzed). The experiment was more or less of a failure because of my use of fairly large creek chubs (*S. atromaculatus*) as the test fish. Six were placed in .08 ppm aldrin in each aquarium; there were no deaths within a week. At least I can say that none of the waters greatly increased the toxicity of the poison.

To test the effect of artificial aeration on the toxicity of aldrin, I set up two aquariums with 15 liters of water and 1 ppm aldrin. An air stone was placed in one aquarium, and air was bubbled through it for 48 hours. At the end of this time, the oxygen was about 9 ppm in each aquarium. Twelve small minnows were placed in each aquarium. In the aquarium that had been pre-aerated, only one fish was dead at 15 hours; in the other aquarium, only one fish was alive at 15 hours.

The bulk of the study was concerned with the comparative sensitivity of various species and sizes of fishes to aldrin. For this phase of the project, a 14-foot aluminum boat was used as the poisoning chamber. It was large enough to test several species simultaneously in 300 liters of water. The water used was the same pond water mentioned previously. Fish were held in the unpoisoned water for three days, during which time injured or diseased specimens were discarded. No food was given during the experiments. At the end of the three days, enough aldrin in water emulsion was introduced to make a concentration of .0164 ppm of the active principle. The same amount was added at four-hour intervals thereafter, throughout each experiment. The aldrin was always scattered over the surface drop by drop and then was mixed with the water in the boat by means of a circulating pump.

In one boat experiment, 275 fish were used. The water was aerated through air stones, and the oxygen level was 6 ppm at the start of the poisoning. It arose gradually to 8 ppm as the number of live fish decreased. The temperature in this test, which lasted for some 250 hours, fluctuated between 17 degrees and 26 degrees C. As the fish died, they were sorted into ½-inch size groups.

In the above experiment, small centrachids of all three species present in the boat were the first fish to die, at about 40 hours and .2 ppm aldrin, along with some small spotfin shiners. By 96 hours, after .4 ppm aldrin had been added, median deaths had occurred among 1½-inch bluegills (*L. machrochirus*) and green sunfish (*L. cyanellus*), 2-inch redfin shiners, and 2½-inch largemouth bass (*M. salmoides*). At 144 hours and .6 ppm aldrin, median deaths had occurred among 2-inch spotfins, 2-inch bluegills, 2-inch river shiners (*N. blennius*), 3-inch green sunfish, and 4-inch common shiners. By 192 hours and .6 ppm aldrin, median deaths had occurred among large adults of the following species: 1½-inch blackstripe topminnows (*F. notatus*), 2-inch fantail darters (*E. flabellare*), 3-inch spotfin shiners, and 3-inch madtoms. By 240 hours and .8 ppm aldrin, median deaths had occurred among large adults of the following species: 2-inch Johnny darters (*E. nigrum*), 2-inch rainbow darters (*E. caeruleum*), and 2½-inch greenside darters (*E. blennioides*). At 250 hours and the conclusion of thet test, median deaths had not occurred among large adult 5-inch stonerollers (*C. anamalum*) and 5½-inch hogsuckers (*H. nigricans*). Note that by the end of this experiment, about 30 times the recognized lethal dose (96 hour median tolerance limit) of aldrin had been administered.

In two more experiments that I will outline briefly, no artificial aeration was provided. Even though the dissolved oxygen did not fall to levels that in themselves would have been fatal, the lack of aeration seemingly was responsible for two important effects: The survival times were much shortened, and the various darters, which had been among the most resistant species with aeration, reversed their position and became among the most sensitive of species.

In one of these experiments, the oxygen stayed between 5 and 6 ppm. Small darters began dying at 30 hours and .12 ppm aldrin. By 40 hours and .17 ppm aldrin, the median 1½-inch spotfin, the median 1½-inch common shiners, and the median 2-inch greenside darter had died. By 50 hours and .21 ppm aldrin, the median 2-inch Johnny darter and 2-inch rainbow darter had died, as had the median 2-inch silverjaw minnow (*E. buccata*). By 60 hours and .25 ppm aldrin, the median adult 3-inch spotfin shiner and the median 3½-inch silvery minnow (*H. nuchalis*) had died. The median 2-inch river shiner died at 78 hours.

In the other experiment, in which the oxygen dropped to a range of 3 to 4 ppm, immature centrarchids (bluegills, green sunfish, and large-mouth bass) died before mature minnows (common shiners, stonerollers, spotfin shiners, and creek chubs). Among the centrarchids, bluegills of 2 inches died at approximately the same time as bass of 5 inches, and bluegills of 3 inches died at approximately the same time as bass of 7 inches.

To summarize the work, it appears that, among the fishes I used, closely related fish are affected similarly by aldrin. The most sensitive fishes were small centrarchids of all three species, together with small members of three species of shiners (common, spotfin, and redfin).

It would appear that aeration not only dissipates aldrin to some extent but also affects the fishes and their survival times directly. Aeration's effect on survival time is not the same for all species. Adult Johnny, greenside, rainbow, and fantail darters were comparatively sensitive at low levels of oxygen and resistant at the higher levels characteristic of their natural environment. Certainly the dissolved oxygen should be recorded most carefully in toxicity studies and should probably be kept at saturation for median tolerance tests. So far as I can tell from the literature, this has not often been done in the past.

The aldrin needed to kill fish varies greatly (at least up to 30-fold), depending on how it is administered. It seems likely that in natural waters many times the dose calculated from median tolerance limits would be needed to effect a fish kill. I say this because in natural waters there would probably be a high oxygen content, photosynthetic aeration, and slow mixing.

Immature fish in general die more rapidly than mature fish in aldrin concentrations. All of the adult fish in the artificially aerated experiments survived longer than fish which were half-grown or smaller, regardless of species.

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